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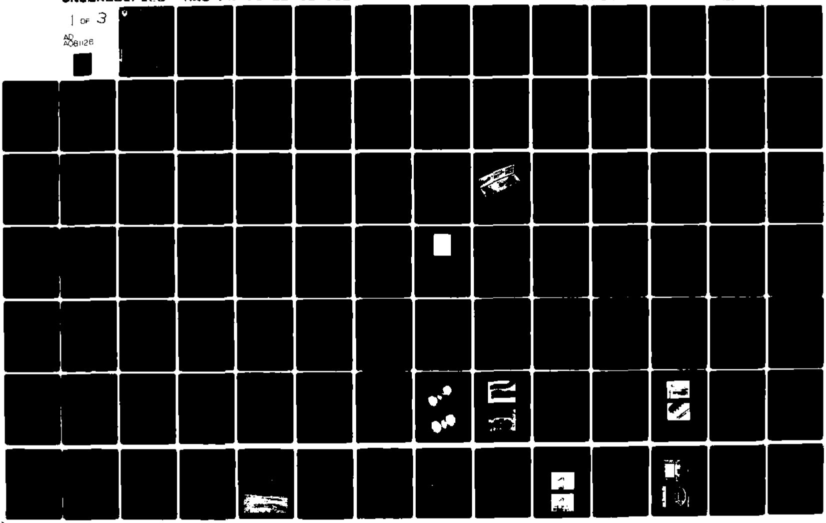

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Research and Development Technical Report
DELET-TR-75-0044-F

PHOTOLITHOGRAPHIC TECHNIQUES FOR SURFACE ACOUSTIC WAVE (SAW) DEVICES

A. W. DOZIER

GROUND SYSTEMS GROUP
HUGHES AIRCRAFT COMPANY
FULLERTON, CALIFORNIA 92634

July 1975 to December 1978

Final Report: Volume 4 – Technical and Operational Parts 4,5

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The object of the program was the establishment of a production capability for surface acoustic wave devices of varied design and material for the purpose of meeting estimated military needs for a period of two years after the completion of the contract, and to establish a base and plans which may be used to meet expanded requirements. The primary requirement was the pilot line production of devices that are reliable, reproducible, and low cost.

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The first phase of this program required the design, fabrication and testing of a total of 60 prototype bandpass, tapped delay line and pulse compression SAW filters on both lithium niobate and ST-quartz. The First Engineering Phase (Phase I) electrical testing demonstrated that the device designs generally met the specifications imposed by the program. Deviations from specification, which required additional test to optimize the levels of padding and/or shunt resistance and capacitance, were resolved during the Second Engineering Phase (Phase II) for the PC-Q, PC-LN and TDL-200. Deviations from the insertion loss specification occurred with the BP-LN and TDL-100 designs. In the former case, a redesign excluding the program-specified multi-strip coupler, was theoretically evaluated. In the latter case, as pointed out in the Hughes proposal, a theoretical analysis precluded the possibility of a specification accommodation. It was necessary to revise the specification for both designs since the customer insisted on utilization of the multistrip coupler in the BP-LN.

Testing of modified semiconductor pin packages during Phase II demonstrated these to be suitable, cost-effective replacements for the machined chassis employed for Phase I. A Quartz orientation problem was highlighted in Phase I and negotiated during Phase II. The quartz vendor implemented an effective screening procedure for the off-orientation problem. However, problems with this vendor continued in the form of substrate surface defects. Other major yield problems encountered during these portions of the program resulted from the dicing and mask making operations. The Phase I and Phase II efforts resulted in a finalized layout, electrical specifications and test procedure for the Third Engineering Phase (Phase III).

Phase III involved fabrication of a larger quantity ~~(50 ea.)~~ of confirmatory devices which were sampled at a high rate and subjected to rigorous life and environmental testing. Phase III was successfully completed with delivery and acceptance of the confirmatory samples. The device configuration is detailed as it existed for Phase III along with assembly details, results and conclusions from the Confirmatory Sample production run. ~~(Phase III)~~.

The Fourth Engineering Phase (Phase IV) of the program was pilot line production effort of 150 each of the devices scheduled to be delivered. Solder sealing was identified as a problem area during Phase IV for SAW devices in semiconductor pin packages. New solder seal screening and processing procedures were investigated. In addition, alternative sealing approaches were evaluated. These procedures, Tungsten Inert Gas (TIG) and projection and seam welding were demonstrated to be more compatible with SAW processing. They are especially suitable for high volume production.

Phase IV pilot line production was completed with the delivery of approximately 150 of each of the device types. Some devices were shipped short due to the inability to locate a second source for projection welding, and the extended lead time in reprocurement of packages capable of being sealed by alternate procedures.

Data from Phases I through IV are presented in the Technical and Operational Volume of the Final Report. Pilot Line process flow and related documentation are presented in the Process Specification Volume of the Final Report. All inspection positions, and quality control procedures for Phase IV are presented in the Quality Control Volume of the Final Report. Cost analysis and labor distribution for all facets of the program are covered in a non-distributable volume of the final report.

The program will include preparation of a General Report, which will consist of an analysis of equipment and facilities required to produce SAW devices of the type produced in the Pilot Run at a rate of 500 per month. In addition, an Industry Demonstration was prepared which verbally and visually presented all facets of the MMT program through the Pilot Run.

CONTENTS OF VOLUME 2, PARTS 1 AND 2

CONTENTS OF VOLUME 3, PART 3

CONTENTS OF VOLUME 4, PARTS 4, 5, AND 6

CONTENTS OF VOLUME 4, PARTS 4, 5, AND 6 (Continued)

APPENDICES FOR VOLUME 2, PARTS 1 AND 2

APPENDICES FOR VOLUME 3, PART 3

APPENDICES FOR VOLUME 4, PARTS 4, 5 AND 6

LIST OF FIGURES FOR VOLUME 2, PARTS 1 AND 2

LIST OF FIGURES FOR VOLUME 2, PARTS 1 AND 2 (Cont'd)

LIST OF FIGURES FOR VOLUME 3, PART 3

LIST OF FIGURES FOR VOLUME 4, PARTS 4, 5 AND 6

LIST OF TABLES FOR VOLUME 2, PARTS 1 AND 2

LIST OF TABLES FOR VOLUME 3, PART 3

LIST OF TABLES FOR VOLUME 4, PARTS 4, 5

LIST OF TABLES FOR VOLUME 4, PARTS 4, 5 (Cont'd)

PURPOSE

This report presents the results of the three year effort in satisfying the requirements of a Manufacturing Methods and Technology Program devoted to a representative range of surface acoustic wave (SAW) device designs.

The objective of this program was to establish a production capability for the purpose of meeting estimated military needs for a period of two years after the completion of the contract, and to establish a base and plans which may be used to meet expanded requirements. The manufacturing method emphasized the photolithographic fabrication of SAW devices that are reliable and reprodicible at low cost.

Specific tasks included establishing and demonstrating a capability to manufacture the six SAW device designs on a pilot line basis using methods and processes suitable for a production rate of 150 devices per month for each type. In addition, engineering analysis and planning remains to be accomplished for expansion of the manufacturing capability which could accommodate the production of such devices at a rate of 500 each per month. This analysis and planning will be delivered in the General Report.

The program was divided into four phases. The first (Phase I First Engineering Sample) addressed the design, fabrication and analytical testing of six prototype SAW devices that are representative of the major current and potential application of the technology. While these device requirements did not represent the state-of-the-art in an R & D sense, they were of such complexity as to require a serious design effort in each case.

The second phase (Phase II – Second Engineering Samples) was performed to redesign those devices that failed the intended design specification. The net result of this effort was to be functional electrical specification adherence, based on a cost effective packaging commitment.

The third phase (Phase III – Confirmatory Samples) was to test and conform to specification for both the electrical and environmental commitment of the various devices. The final phase (Phase IV – Pilot Run) was to test the reproducibility of those predetermined electrical and environmental requirements in a high volume (150 per month) production environment. A key result of this phase was the establishment of meaningful manufacturing cost data on each device as well as a comparison of this data to the prior low volume efforts of the earlier phases. These data will then be extrapolated to a production rate of 500 per month with assumptions regarding facilities and equipment in the General Report.

GLOSSARY

SAW	–	Surface Acoustic Wave
BP-Q	–	Bandpass Filter – ST Quartz Substrate
BP-LN	–	Bandpass Filter – Lithium Niobate Substrate
TDL-100	–	Tapped Delay Line Filter – 100 MHz – ST Quartz Substrate
TDL-200	–	Tapped Delay Line – 200 MHz – ST Quartz Substrate
PC-Q	–	Pulse Compression Filter – ST Quartz Substrate
PE-Q	–	Pules Expansion Filter – ST Quartz Substrate
PC-LN	–	Pulse Compression Filter – Lithium Niobate Substrate
PE-LN	–	Pulse Expansion Filter – Lithium Niobate Substrate
ST	–	Quartz orientation, ST cut (42^o 45'), X propagating
YZ	–	Lithium Niobate orientation, Y cut Z propagating
TIG	–	Tungsten Inert Gas Welding
MSC	–	Multistrip Coupler
K^2	–	Electromechanical Coupling Constant
f_o	–	Center frequency
B	–	Bandwidth
T	–	Time Delay
TXB	–	Time Bandwidth Product
VSWR	–	Voltage Standing Wave Ratio
DUT	–	Device Under Test
L_{INS}	–	Insertion Loss
$S_{S.L.}$	–	Sidelobe Suppression
$S_{f.t.}$	–	Feedthrough Suppression
S_{Spur}	–	Spurious Suppression
TTS	–	Triple Transit Signal

4.0.0
CONFIRMATORY SAMPLE FABRICATION, ELECTRICAL AND ENVIRONMENTAL TEST (PHASE III)

4.0.0 CONFIRMATORY SAMPLE FABRICATION, ELECTRICAL AND ENVIRONMENTAL TEST (PHASE III)

As mentioned in Volume III of the Final Report, Phase II of this program finalized the mechanical configuration of the six part types designed for this contract. Standard hybrid packaging approaches were utilized in the final design in order to meet the environmental requirements of Phases III and IV. However, the new packaging format, along with transducer and tuning network design tradeoffs, yielded electrical performance which did not meet the original specification requirements. (Appendix I, Volume II of the Final Report.) As a result, the specification was renegotiated to reflect finalized values based on the redesign (Appendix IX, Volume III of the Final Report). In addition, processing approaches and equipment choices were finalized during Phase II in anticipation of the balanced pilot production line and production rates required for Phase IV. The processes, and device mechanical/electrical requirements which were chosen for Phases III and IV have been detailed in Volume I, and Appendix IX of Volume III of the Final Report.

Goals of Phase III of this program were: delivery of fifty specimens of each part type to the finalized electrical and mechanical requirements mentioned above; subjection of these parts to the requirements for First Article Inspection detailed in Paragraph 4.4, Appendix IX, Volume III of the Final Report. It should be noted that hermeticity was required for Phase III specimens per the requirements of paragraph 4.6.5, Appendix IX, Volume III of the Final Report. This required solder sealing of devices, rather than the tack soldering of lids to the header described for Phase II. Also, although processes and equipment were finalized for Phases II and IV prior to initiation of Phase III, the final production line layout and pilot production rate requirements were not totally in effect during Phase III.

This section will be divided into four segments. The first (Section 4.1.0) will reiterate the design approach outlined in Volume III with additional comments on package sealing. Section 4.2.0 will detail equipment utilized to fabricate and test the Phase III devices. However, details of pilot line layout, equipment cost and capacity, and facilities requirements will be discussed in the section on Pilot Line implementation and Pilot Production. (Section 5.1.0.) The third section (Section 4.3.0) will detail modifications to the Sampling Plan, First Article Test Flow, and First Article test procedures. Section 4.3.4 will consist of a presentation of First Article test data. This will be followed by sections discussing failures (Section 4.5.0) and conclusions from Phase II (Section 4.6.0).

4.1.0 DEVICE CONFIGURATION FOR PHASE III

As was mentioned in Volume III of the Final Report, Tekform 20221 and 20117 headers were chosen for the final phase packaging. Header layout utilized was outlined in Volume III, and is reiterated in Figure 4.1-1. These headers are designed to be either solder sealed using a hand soldering iron or projection welded, depending on the lid configuration chosen (See Figure 4.1-2). As can be seen, hermeticity depends upon good wetting in the areas of the solder fillet. In order to promote wetting, both lids and headers were ordered with tin plating which was subsequently fused in the oil bath. Only the pins in the headers were gold plated. The

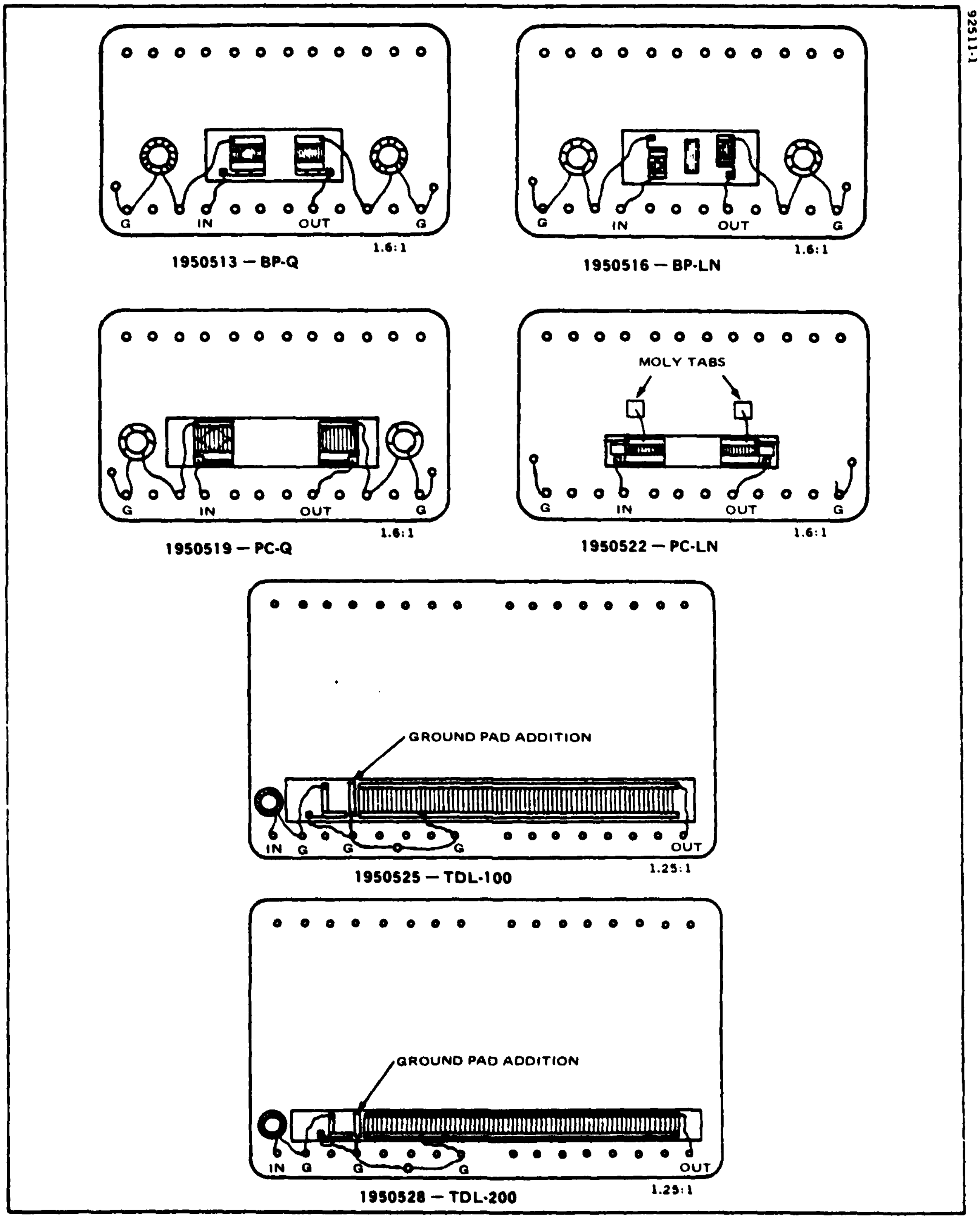

Figure 4.1-1. MMT SAW Device Final Configuration

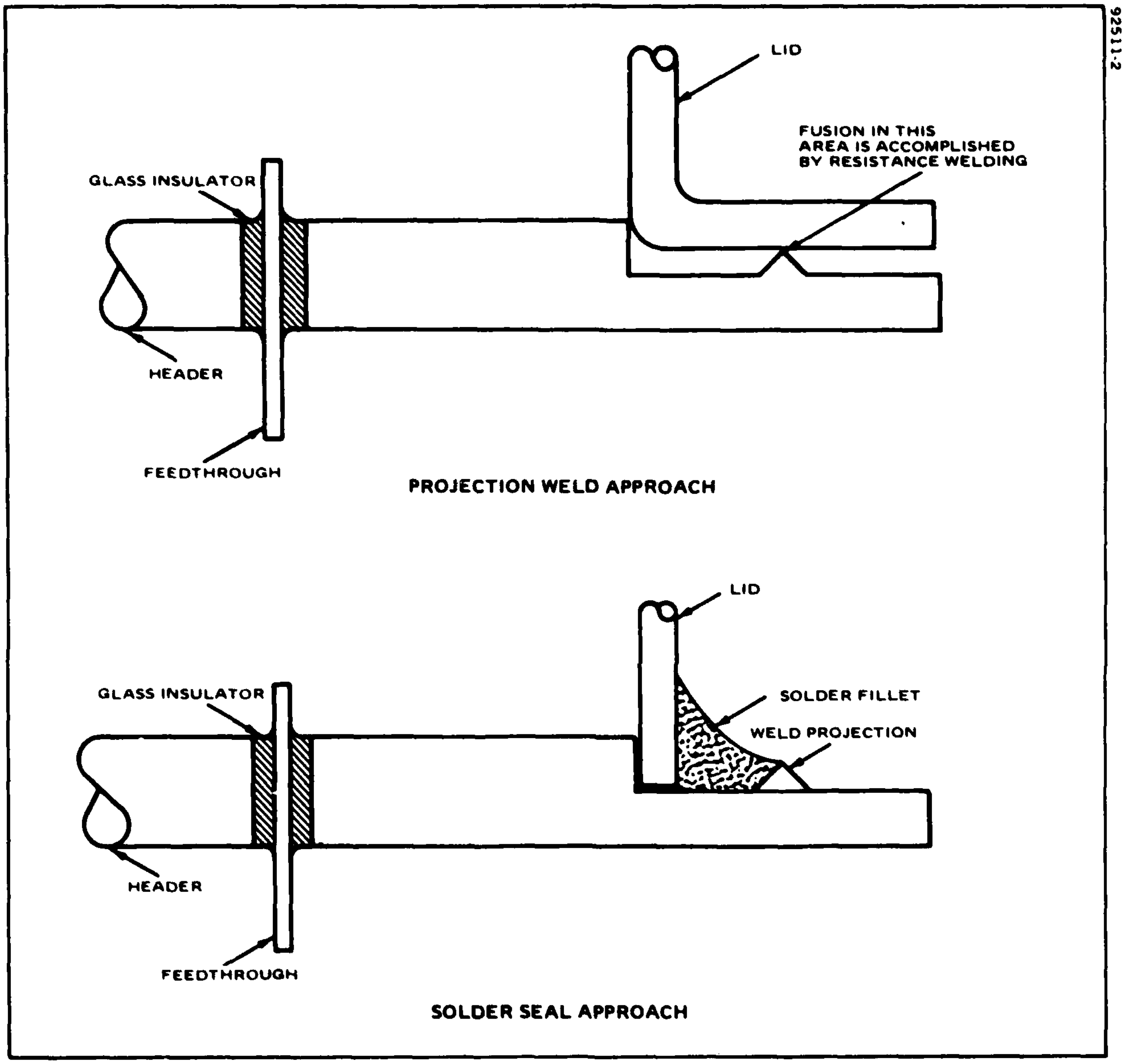

Figure 4.1-2. Sealing Configurations for Tekform 20221 and 20117 Headers

impact of the tin plated headers on device layout and assembly are discussed in Section 3.2.6 of Volume III of the Final Report. Lids were only tack soldered on the assembly bench for Phase II to effect good grounding of the lid to the header. However, for Phases III and IV, packages were subjected to a two hour vacuum bake at 125°C, transported directly into a dry nitrogen box (moisture content of the dry box atmosphere was 20 ppm by volume, maximum), and sealed in the drybox using a hand soldering iron (Ungar, 50 watt tip) with application of solid Sn 63 solder (QQ-S-571). No flux was used in the sealing operation.

4.2.0 TEST EQUIPMENT AND PROCESSING

As was mentioned previously, all processes and equipment were finalized at the completion of Phase II. However, due to the low production rates required for confirmatory sample fabrication and test, the pilot production line layout was not finalized at this point in the program. Production line layout, capacity and cost will be detailed in the Section 5.1.0. Equipment required to fabricate and inspect the devices for Phase III can be seen in Table 4.2.1.

As was mentioned in Section 3.2.6, Volume 3 of the Final Report, the electrical test fixture is extremely important with regard to feedthrough for the designs fabricated on this program. The test fixture outlined in Figure 4.2-1 was utilized for all electrical tests during Phase III. It should be noted that this test fixture precluded final electrical test of the devices subjected to solderability testing per paragraph 3.8, Appendix IX, Volume III (Group II Testing), since the package pins would not insert into the SMA connector barrels of the test fixture without damage.

Electrical test equipment utilized to perform acceptance testing of the devices per drawing Number 1950512-800, Volume I of the Final Report is listed in Table 4.2-2. Environmental test equipment required to perform those tests in Group VI testing, Table IV, Appendix IX, Volume III, is listed in the appendix on environmental test (Appendix XI).

4.3.0 FIRST ARTICLE INSPECTION

This section describes the confirmatory phase (Phase III) fabrication and test flow, sampling plan, and test requirements and procedures. At the conclusion of first article testing fifty each of the first article test devices were delivered under Supplies Line Item OOO1AB of the contract in fulfillment of the Confirmatory Phase of the contract. First article test samples were construed to be deliverable with the cognizance of the customer, since no mention of deliverability was made in the contract.

4.3.1 Fabrication and Test Flow

Device fabrication and first article test flow can be seen in Table 4.3-1. Processes utilized are those detailed in Volume I of the Final Report, and equipment utilized was outlined in Section 4.2.0. Precap testing was witnessed by the Quality organization. All wafers were subjected to the first article inspection called out in Table III of Appendix IX. After precap electrical test, parts passing test requirements were sent to the sealing station and processed as outlined in Section 4.2.0. As can be seen

TABLE 4.2-1. EQUIPMENT REQUIRED FOR DEVICE FABRICATION

	HAC I.D. No.
Capital Equipment	
Laminar Flow Hood with Process Sink (1 ea)	-
*Veeco VE400 Vacuum System	H187549
Veeco Thermocouple Gauges	H187549
Airco Power Cabinet	H339253
Airco CV-8 SMH 270-2M Controller	H334727
CVC Model LC 031 Hi-Voltage Power Supply	H103753-1
Imficon XMS-3 Rate Monitor	H334727
*SSEC Model 103 Resist Spinner	H334677
*Kasper 1800 Mask Aligner	H225148
*Thelco Oven	-
Laminar Flow Benches (5 ea)	-
Dektak Profilometer	H198478
*Carl Zeiss Microscope	H342904
*Vickers Image Shearing Microscope	H327672
Electroglass Dicing Saw	H339306
B&L 20x Microscope (3 ea)	-
RTV Dispensing Machine	CAR #529812
Hughes Thermopulse Wire Bonder	H302728
Dry Box with Integral Vacuum Oven	
Mech El Bond Pull Tester, Veeco Leak Detector	
Miscellaneous	
Wafer holding fixtures, tweezers	
Petri dishes, beakers, etc.	
Resist dispensers (eyedropper)	
Desiccators, dry nitrogen storage cabinets	
Hot plates, soldering irons	
Ultrasonic cleaner	

*Indicates equipment under laminar flow benches

from Table 4.3-1, a sample was then pulled for the lead integrity test required in paragraph 4.6.4.2 of Appendix IX. One hundred percent of parts coming from the package seal station were subjected to hermeticity test. Hermeticity rejects were high for this phase of the program, approaching 40 percent for some part types. Hermeticity rejects were chosen to be subjected to the lead solderability test (Group II), since lead solderability is not related to package hermeticity. These parts were not electrically tested due to inability to fit in the test fixture. Tests from the non-destructive Bond Pull Test operation to the visual inspection operation after acceptance electrical in Table 4.3-1 comprise the requirements of Group I test for 100% of the devices entering environmental high temperature storage and operating life test (Group III and IV test).

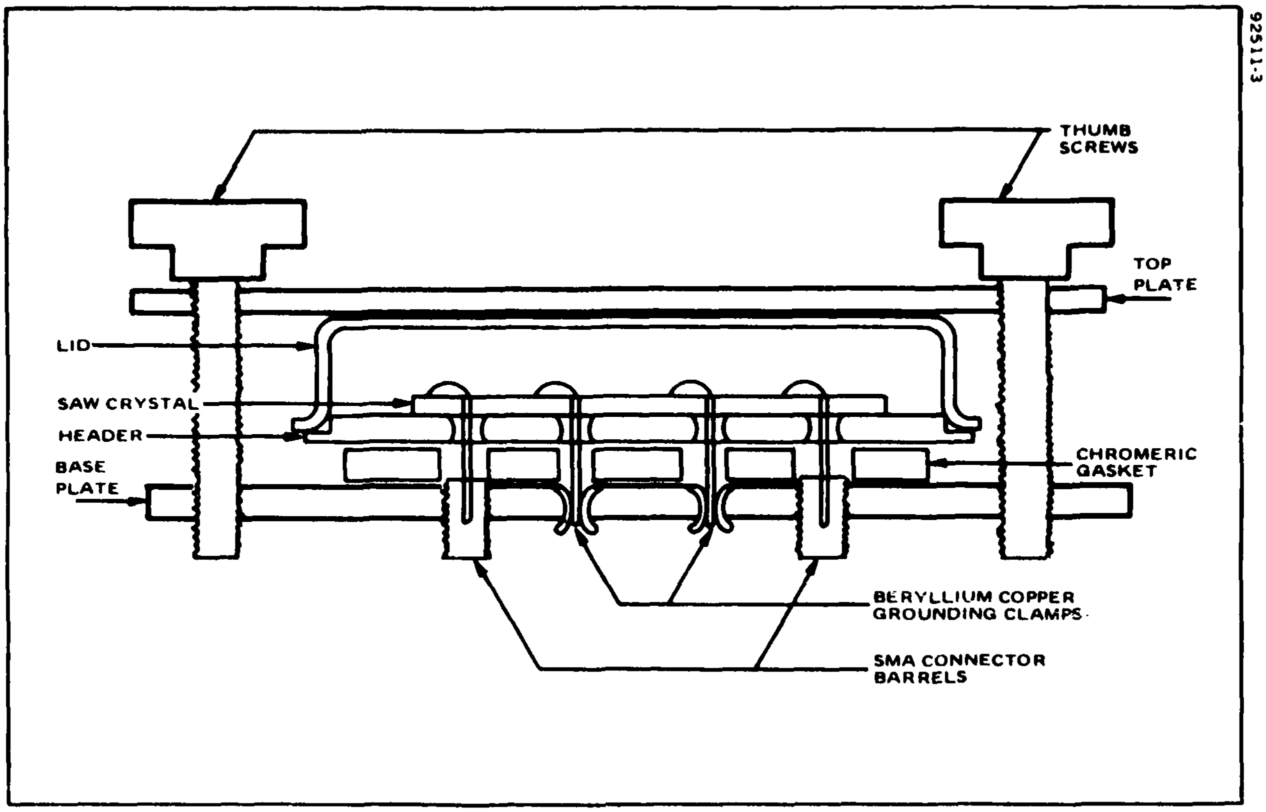

Figure 4.2-1. Schematic Cross Section of Improved Electrical Test Fixture Utilized for Phases II, III and IV

Since all devices (fifty each) were subjected to hermeticity test, all specimens coming out of Group I test were subjected to the short circuit test in fulfillment of the Group V test requirement outlined in Table IV, Appendix IX. The balance of the parts were subjected to either of Groups III, IV, and VI test procedures. A request was made of ECOM to perform tests in Groups III and IV serially, since it was felt that there would be no rejects for this series of tests and Method 5008 of MIL STD 883 recommends the use of the high temperature storage test "...in a screening sequence, or as a preconditioning treatment prior to the conduct of other tests..." Endpoints per the requirements of Table IV, Appendix IX (f_0 and L_{ins}) were made after Group III test to detect failures. All parts passed and were subsequently subjected to Group IV testing. The remainder of all part types were subjected to Group VI testing. After Groups III, IV, and VI test, all parts were subjected to a complete acceptance test procedure per HAC drawing number 1950512-800 which can be seen in Volume I of the Final Report.

TABLE 4.2-2. ELECTRICAL TEST EQUIPMENT

Instr.	Mfg.	Model	HAC No.	Accuracy
Oscilloscope	Alfred	8000	H-190035	2%
Sweep network analyzer	Alfred	7051	H-190036	2%
Amplifier	Avantek	UTA311N	*SN13	
Amplifier	Avantek	UTA311M	*SN14	
Amplifier	Avantek	UTA311M	*SN14	
Amplifier	Avantek	UTA311M	*SN15	
Amplifier	Avantek	AV9-M	*SN51	
Pulse generator	E-H Research Lab	139B	H190151	
Power supply	Hewlett Packard	6215A	H958495	3%
Power supply	Hewlett Packard	6215A	H-958496	3%
Crystal detector	Hewlett Packard	423A		±0.5 dB
Attenuator	Hewlett Packard	355C	H958836	±0.25 dB
Attenuator	Hewlett Packard	355D	H958837	±1.5 dB
Attenuator	Hewlett Packard	355C	H958498	±0.25 dB
Attenuator	Hewlett Packard	355D	H958497	±1.5 dB
Oscilloscope	Hewlett Packard	183A	H201430	3%
Dual Channel Vert. Amplifier	Hewlett Packard	1830A	H201431	3%
Time Base and Delay Generator	Hewlett Packard	1841A	H202632	3%
Electronic counter	Hewlett Packard	5246L	H187619	±1 count
Frequency converter	Hewlett Packard	5253B	H182632	±1 count
VHF Signal Generator	Hewlett Packard	608D	H40267	0.05%
Oscilloscope	Tektronix	535A	H-76288	3%
Dual trace plug in	Tektronix	1A1	H-187690	3%
Rho-tector	Telonic	TRB-1	*4076-56	5%
Termination	Telonic	TRM-1-1.00F	*4099-3	5%
Sweep/Signal Generator	Wavetech	2001	H-342966	5%

*Asterisked equipment was not procured as capital equipment and is therefore designated by manufacturer sample number or lot date code of manufacture.

All parts were then subjected to a sample visual inspection by the Quality organization. Fifty each of the parts subjected to the above testing were selected and shipped as deliverables for the Confirmatory Sample Phase of the contract.

4.3.2 Sampling Plan

As was inferred from Section 4.3.1, the sampling plan utilized for Phase III was modified slightly from that required in the original specification (Appendix IV). In all cases, engineering judgement was applied to make testing sequences fit logically with the product fabrication flow. A summary of the sampling plan utilized for first article test can be seen in Table 4.3-2. Differences between requirements called out in Appendix IX, Volume III, and Table 4.3-2 are: Group III and Group IV testing was combined, i.e., performed on the same sample; Group V test was performed on

TABLE 4.3-1. PHASE III FABRICATION AND TEST FLOW

Wafer First Article Inspection

Clean Wafer

Metallization Deposition

Photolithography

Visual Inspection (250X, Para 3.2.4.1, 3.17, 4.6.1.1)

Die Marking

Metallization Adhesion (Para 3.2.1.2, 4.6.2)

Short Circuit (Para 3.9 and 4.6.8)

Wafer Dicing

Visual Inspection (20X - Para 3.2.4.2, 4.6.1.2)

Die Attach

Toroid Attach

Wire Bond

Non destructive Bond Pull Test (Para 3.5.2, 4.6.4.1)
10 Devices of each Part Type

Group I

Pre cap Tune and Acceptance Electrical Test - Para 3.10

Visual Inspection (20X - Para 3.2.4.2)

Package Seal

Lead Integrity (Para 3.5.2, 4.6.4.2 Sample of 10 Devices)

Hermeticity Test

Marking (Para 3.16)

Acceptance Electrical Test - Para 3.10

Visual Inspection (20X Para 3.2.4.2)

Group V

Short Circuit Test (Para 3.9)

9 each - TDL, 18 each All Others — Group IV — Group III

High Temp. Storage
Non operating (Para 3.11)

Electrical Test
Para 3.10.1 and 3.10.5

Operating Life
(Para 3.15)

Acceptance Electrical
Test - Para 3.10

12 each TDL, 24 each - All Others — Group VI

6 ea - TDL, 12 ea - All Other

6ea - TDL, 12 ea - All Others — Group II

Environmental
Test (Para 3.12,
3.13, 3.14, 3.7)

Acceptance
Electrical
Test
Para 3.10

Solderability
(Para 3.8)

Visual
Inspection
(20X Para
3.2.4.2)

Visual Inspection
(20X - Para 3.2.4.2
AQL = 4.0)

Pack

Ship

Note:

1. All inspection and electrical tests are 100% of devices/wafers at that point unless otherwise notes.

TABLE 4.3-2. PHASE III SAMPLING PLAN

TDL 200	TDL 100	BP-LN	BP-Q	PC-LN	PC-Q	
18 (8)	18 (8)	11 (11)	11 (11)	11 (11)	11 (11)	No. Wafers Fabricated[1]
12	9	32	33	45	20	No. Die per Wafer
166 (42)	127 (42)	190 (84)	221 (84)	261 (84)	122 (84)	No. Visually Acceptable Die[2]
77	78	54	61	53	56	Percent Passing Visual Inspection.
16 (6)	6 (6)	12 (12)	12 (12)	12 (12)	12 (12)	Submit for Group II Devices Test.[3]
67	73	56	54	54	58	Devices Passing Post Seal Acceptance Test
27	27	50	50	50	50	Min. Sample Required for Group I, and First Article Test of Devices.[4]
9	9	18	18	18	18	Min. Sample Required for Group III.[4]
9	9	18	18	18	18	Min. Sample Required for Group IV.[4]
6	6	12	12	12	12	Min. Sample Required for Group V.[5]
12	12	24	24	24	24	Min. Sample Required for Group VI.
0 1 0 1	0 1 0 1	0 1 0 2	0 1 0 2	0 1 0 2	0 1 0 2	No. Defective (Max.)

Notes:

1. Program requirements (Table II, Appendix IX, Volume III of the Final Report) are in parentheses.
2. "Operable" in Table II listed above has been interpreted as meeting the visual requirements of an inspection standard which has been demonstrated to meet the electrical requirements of the program. Minimum program requirements are in parentheses.
3. Devices submitted for this test were hermeticity rejects, which had previously passed precap acceptance test. Hermeticity failures have no bearing on lead solderability, and solder tinned leads do not allow insertion of the specimen into the test fixture. Minimum program requirements are in parentheses.
4. Groups III and IV testing were performed sequentially, thereby reducing the total sample size.
5. Group V test was performed on all specimens passing Group I test.

100 percent of parts passing Group I test, rather than a sample of 12 or 9 devices, depending on the part type; f_o and L_1ns, per paragraph 3.10.1 and 3.10.5 of Appendix IX, were determined between Group III and Group IV test to ascertain where failures occured, [The combination of Group III and Group IV test caused a reduction in the sample size required for Group I testing]; and Group II test was performed on hermeticity rejects.

4.3.3 Test Requirements and Procedures

A summary of first article inspection requirements for completed devices can be seen in Table 4.3-3. In addition, other requirements were imposed at the wafer level in Table III, Appendix IX, Volume III of the Final Report. Discussion of the wafer evaluation requirements and procedures will be followed by discussion of the individual tests in the sequence listed in Table 4.3-3.

4.3.3.1 Wafer First Article Inspection Requirements

After pattern definition, wafers were subjected to a linewidth measurement using a Vickers image shearing microscope. They were then placed at the visual inspection station, and each die inspected individually using a Carl Zeiss microscope at 250X to the inspection requirements outlined in Table 4.3-4. The requirements outlined in Table 4.3-4 were derived from a correlation between electrical performance and visual flaws on specimens fabricated during Phases I and II of the program. These requirements embodied the reference standard called out in Table III, Appendix IX, Volume III.

Wafers were viewed in transmitted light with the exception of trying to discriminate between a metallization short and debris on the surface of the wafer. In this case, it was necessary to switch from transmitted to reflected light. Surface particulates could be distinguished from metallization shorts by determining the focal position variation when viewing the defect.

The depth of focus for this microscope was quite shallow at 250X, and surface particulates would remain in focus when the metallization pattern was lowered from the lens and defocused. This particular microscope was not easily switched from the transmission to the reflected light mode. Mode changes required turning on the reflected light source and decreasing the intensity of the transmission source, entailing taking one's eye away from the microscope and adjusting two switches and two potentiometers.

In addition, as the crystal was inspected, a map of the defective devices was made, enabling marking of the defectives after the entire wafer was inspected. This model microscope did not have an image inverter, since its use was primarily for metallographic work. As a result, the operator had to mentally invert her observations when marking the crystal map in order that it would correlate the inspection rejects to the proper device on the crystal. This was especially tedious for wafers with a large number of devices. These operations were quite time consuming, requiring an average of 1.3 man-hours per wafer for inspection, and undoubtedly leading to the marking of good devices as defective, resulting in the acceptance of visually discrepant die.

Future work of this kind will require an inspection microscope that could be switched from transmission to reflection with the flip of a single switch to

TABLE 4.3-3. PHASE III INSPECTION TEST REQUIREMENTS FOR SAW DEVICES

Applicable Group	Test	MIL-STD	Method	Condition	Comment
I	Wire Bond and Lead Integrity	883	2011	A and D	2 gm tension. Non-destructive pull test. 10 devices
II	Solderability	883	2003	--	--
III	High Temperature Storage	883	1008	A	72 hrs. @ 75°C non-operating
IV	Life	202	108	--	85°C for 500 hrs, operating - 10 MW CW @ f_o.
V	Hermeticity	202	112B	C A	Fine Leak Gross Leak
VI	Vibration	202	201	--	10-55 Mz sweep in one minute, 2 hrs/axis, test 3 axes, non-operating
	Shock	202	213	I	100 G, 6 ms saw-tooth 6 shocks/axis test 3 axes non-operating
	Thermal Shock	202	107	A	10 cycles, -55°C to +85°C air to air, 1/2 hr. dwell non-operating
	Moisture Resistance	202	106D	--	See Figure 4.3.2 w/50 V polarizing voltage applied
I	Visual Inspection	--	--	--	Hughes QMS M-035 (Appendix XII)
I, III, IV, VI	Acceptance Electrical Test Procedure	--	--	--	Hughes Dwg #1950512-800 Volume I, Final Report and Para. 3.10, Appendix IX Volume 3.
V, VI	Short Circuit Test	--	--	--	

TABLE 4.3-4. PHASE III WAFER INSPECTION CRITERIA

	Visual Criteria	Metal Thickness Criteria	Comments
BP-Q	3 opens-active area	2000 Å ± 15%	3.9μm lines, double electrodes source withdrawal and apodized. Transducers
BP-LN	0 open-active area 1 open-inactive area	1000 Å ± 10%	Lins too low - Scribed open fingers on MSC to bring into spec. both trans. apodized, 2.9 μlines
PC-Q	3 opens-active area	1200 Å ± 15%	4.5 to 6.3 μm lines One transducer apodized
PC-LN	3 opens-active area	1500 Å ± 15%	5.0 to 7.0 μm lines One transducer apodized
TDL-100	3 open taps (7 electrodes each)	400 Å ± 10%	3.9 μlines double electrode 7.9 μlines in tap.
TDL-200		Same as TDL-100	

Notes

1. No shorts are allowed in the active area on any device type.
2. Unless otherwise specified, shorts in the inactive area of a device are permissable in any number.

turn on and off the proper combination of light sources. The image inverting feature should also be built into the optics. American Optical Co. has recently come out with such an instrument.

After visual inspection, the wafer map is used to mark good die with a numerical code which defines the wafer number and evaporation lot number. A short circuit probe test was then performed on all devices passing visual inspection. Wafer metallization thickness was measured using the Dektak profilometer. Wafers were then submitted for dicing, and a rejected device retained from each wafer. The rejected sample devices were then submitted for cleaning, after which they were subjected to a tape pull of metallization adhesion test (para. 4.6.2, Appendix IX). After passing the aforementioned test sequence, die from accepted wafer lots were then cleaned, reinspected per QMS M-035 (Appendix XII), assembled to headers, and submitted for the tests detailed in Table 4.3-3.

4.3.3.2 Wire Bond and Lead Integrity

Test Condition A – This procedure calls for the pull test of external package leads with requirements called out in paragraph 4.4.1.2 of Appendix IX. Hughes interpreted this requirement to be 50 gms force

in a direction parallel to the lead axis and no greater than 5 degrees bending of the lead from a direction perpendicular to the plane of the header for the dual-in-line types of packages used on this program. No cracking of the glass bead oter than meniscus cracking such as that defined in MIL-STD-883 was permitted. Hermeticity was required to be retained through this test.

Test Condition D – Although Method 2011 is generally called out as a destructive test, the bond strength required for 2 mil gold wire in Appendix IX (2 gms - paragraph 4.6.4.1) is considerably lower than the destructive bond pull limit specified for 2 mil diameter gold wire (7.4 gms - Figure 2011.1). Hughes interpreted this to mean requirement of a non-destructive bond pull test with details as called out in paragraph 3.4 of Method 5008, MIL-STD-883. Since one mil diameter gold wire was used on these devices, bond pull test requirements were then derived from the MIL-STD to be 1.5 gms pull force. No failures were allowed, in order to pass the first article lot acceptance. A sample of ten specimens was pulled from each device type.

4.3.3.3 Lead Solderability

This test is used to evaluate the solderability of the leads on the hybrid packages utilized for all part types. As was mentioned previously only the pins of the packages were electroplated. Plating sequences used for these leads were electroless nickel, followed by electolytic gold of 50 to 100 micro inches thick. Solder will dewet during this test if the gold plating is of insufficient thickness or porous enough for the underlying base material to oxidize. Hermeticity rejects were tested on the sample basis specified in Section 4.3.2. Prior to solder tinning of the package leads, parts were preconditioned by suspending over boiling deionized water for one hour. The leads were then tinned in a solder pot containing Sn 60 solder for 5 seconds, a period of time sufficient to scavenge all the gold plate on the leads into the solder bath. Tinned parts were then subjected to visual inspection at 10X, with failure criteria being greater than 95 percent dewetting and/or pinholes concentrated in one area greater than 5 percent of the tinned area.

4.3.3.4 High Temperature Storage

Parts sampled per Section 4.3.2 were maintained in an oven at 75°C for a period of 72 hours under ambient atmospheric conditions. The center frequency and insertion loss of the sampled parts was then measured.

4.3.3.5 Life Test

Parts were plugged into test boards similar to the one shown for the BP-Q, BP-LN and PC-Q devices in Figure 4.3.1. Mounting of the parts on the boards was identical to the specimen holder depicted in Figure 4.2.1. Test boards were designed to accomodate the sample size called out in Table 4.3-2, i.e., 18 each for the Bandpass and Pulse Compression devices and 9 each for the TDL devices. It should be noted that in order to meet the requirements of this life test, each part under test must see normal input power levels, i.e., "the device must be performing its operational function."[1] To implement this requirement, an N-way power divider must be used, where

[1] MIL-STD-202E, Method 108A, Section 1.

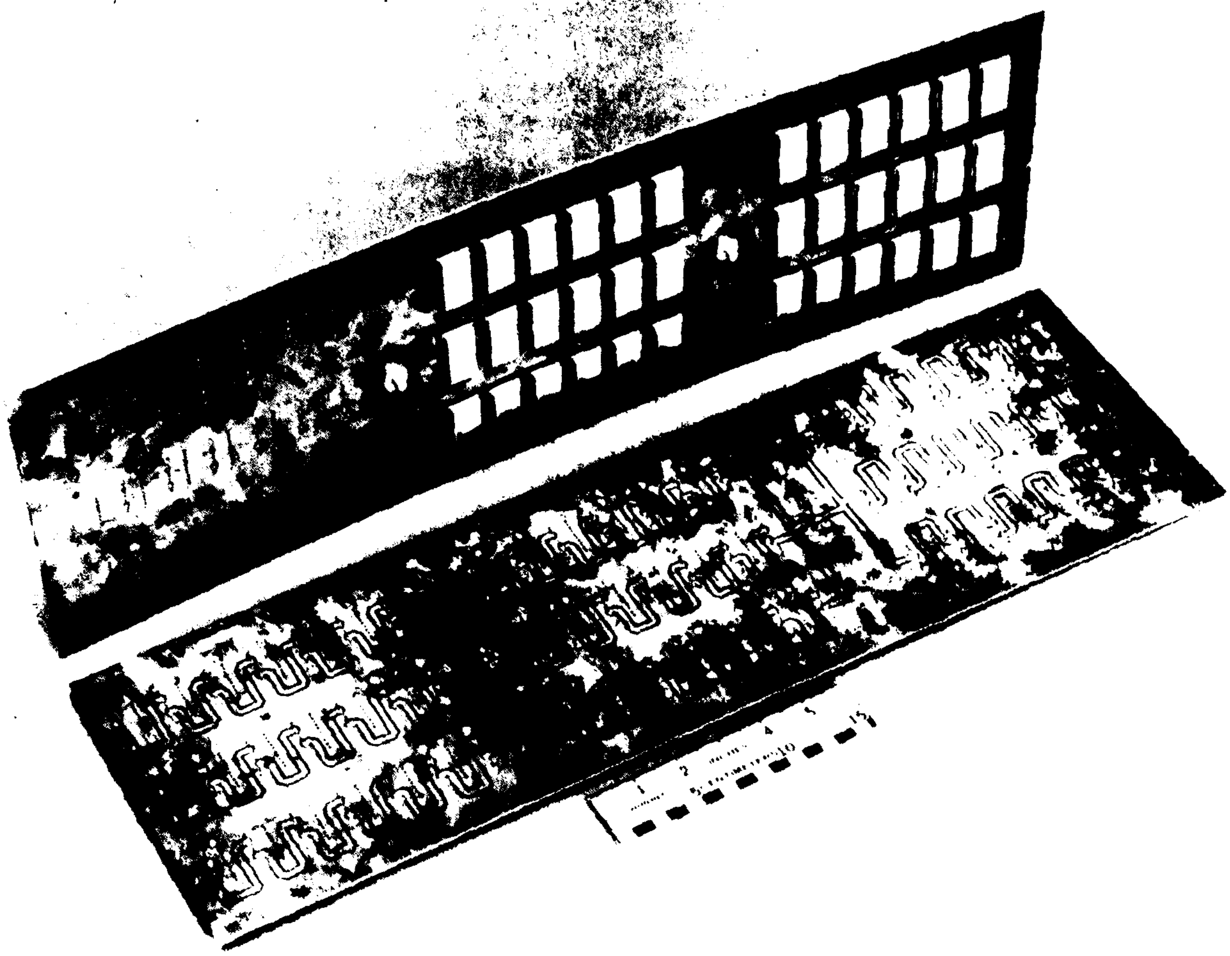

Figure 4.3-1. Typical Printed Circuit Board Layout for Operating Life Test of PCQ, BPLN and BPQ Devices. Parts were inverted into the board in a manner identical to that depicted in Figure 4.2.1. Output of each string of devices was fed into a 50Ω resistor.

N is the sample size for each part type. A suitable configuration to achieve this condition is shown in Figure 4.3-2 for the maximum sample size of eighteen devices. Note that the devices are matched to a 50 ohm line. The test board and equipment configuration depicted in Figure 4.3-2 would cost approximately $1,100. Performance of the 500 hour life test on all parts in a serial fashion would have required eighteen weeks test time. This test time could have been reduced by half with the addition of another test board, but double the equipment cost. In order to test all six parts simultaneously, a more expensive configuration than that depicted in Figure 4.3-2 would have been required. In light of the extensive test time and equipment cost, a life test of reduced scope was implemented, utilizing the test boards depicted in Figure 4.3-1.

Figure 4.3-3 shows a typical configuration of the way the devices were actually tested. Devices were wired in the series-parallel configurations noted in Table 4.3-5. As a result of this wiring configuration, devices in series beyond the first one or two devices saw extremely low power levels, due to the 20 to 55 dB insertion loss of the previous devices. This configuration has the effect of subjecting some devices to essentially a 500 hour high temperature storage test at 85°C. However, the remainder of the devices "performed the operating function", which in essence simply reduced the sample size for the life test. It should be noted that input power levels were not specified in paragraph 4.6.14 of the electrical specification (Appendix IX, Volume III of the Final Report).

4.3.3.6 Hermeticity Test

This is a standard test used in the assembly of all hybrids. Parts were pressurized in a helium bomb at 60 psi for 2 hours. Within 0.5 hours of removal from the helium bomb, parts were subjected to fine leak testing in an automated Veeco leak detector, which was calibrated with a controlled leak traceable to NBS standards at the start of hermeticity test. After performance of fine leak testing, parts are then subjected to gross leak testing by submersion in Freon FC-40 at a temperature of 125°C.

4.3.3.7 Vibration and Shock

Test procedures, specimen fixtures, and equipment are outlined for these tests in Appendix XI. A short circuit test was performed between vibration/shock test, and after shock testing.

4.3.3.8 Thermal Shock and Moisture Resistance

Thermal shock testing was performed in an apparatus that maintained two chambers at -55°C and 85°C with ambient atmospheric conditions. Parts were placed in the cylindrical specimen holder which rotated between the two chambers with a 5 minute dwell between temperature extremes. Thermal capacity of the chambers was such that test chamber temperature reached the required value within two minutes of transporting test specimens into the chamber. Parts were subjected to 10 cycles from -55° to 85°C, followed by subjecting to a short circuit electrical test.

Moisture resistance was performed on the specimens after thermal shock testing. Initially parts were dried in an oven for 24 hours at 50°C, after

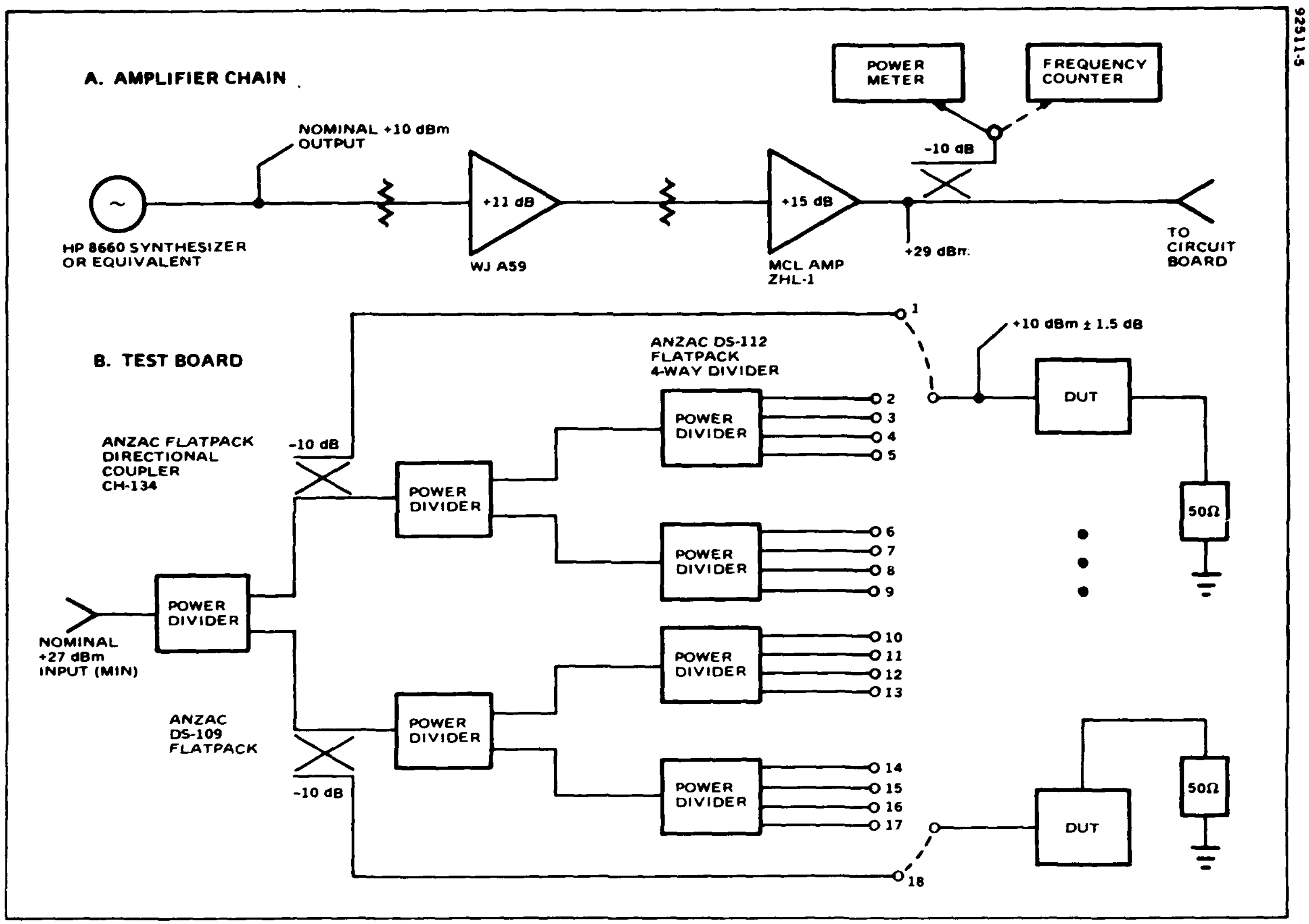

Figure 4.3-2. Recommended Life Test Block Diagram

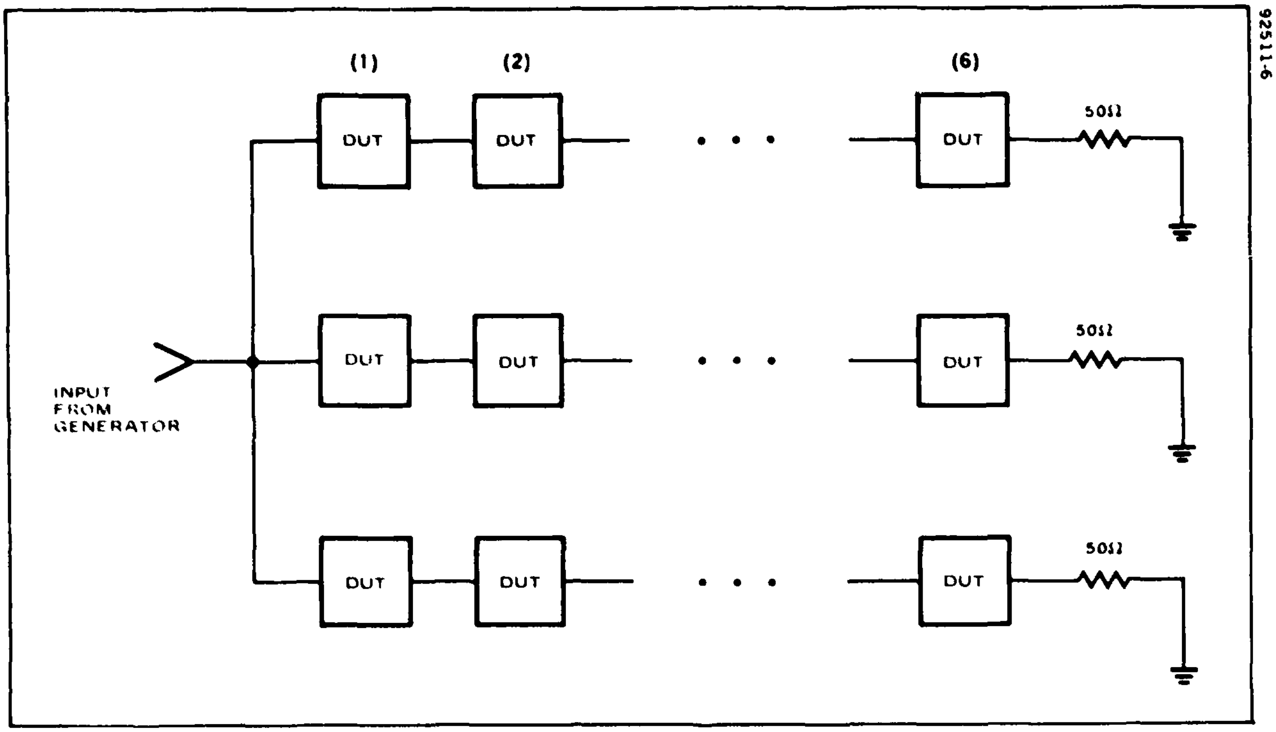

Figure 4.3-3. Typical Life Test Circuit Board Configuration

TABLE 4.3-5 DEVICE LIFE TEST BOARD SCHEMATIC DETAIL

Device Type	F_O (MHz)	Number of Chains in Parallel	Number of Devices in Series per Chain	Termination Resistance
RP-Q	100	3	6	51Ω
BP-LN	150	3	6	51Ω
PC-Q	150	3	6	51Ω
PC-LN	150	2	9	51Ω
TDL-100	100	3	1 @ 6 2 @ 4	51Ω
TDL-200	200	3	1 @ 6 2 @ 4	51Ω

which they were subjected to ten of the cycles represented in Figure 4.3-4. A polarization voltage of 50 V D.C. was applied during the cycle between 25°C and 65°C at 89-98% relative humdity. The polarization voltage was applied by attaching all input and output terminals of the devices under test to the positive terminal of the power supply. All ground terminals were attached to the negative terminal. After the tenth cycle, the parts were removed from the humidity chamber and a complete set of electrical measurements performed per the acceptance test procedure listed in Table 4.3-3 within 2 hours of removal from the chamber. Parts were then measured again after twenty four hours.

4.3.3.9 Device Visual Inspection

Visual inspection requirements can be divided into two areas: crystal die, and requirements related to header assembly. After the wafer inspection at 250X mentioned in section 4.3.3.1, headers are assembled with cleaned die, toroids installed, and precap test performed. Completed headers are then inspected to die requirements outlined in QMS M-035 (Appendix XII). Wire bonds and solder joints are inspected to MIL-STD 883, Method 2017.1.

4.3.3.10 Electrical Test

Acceptance test procedures and equipment are outlined in Hughes Drawing #1950512-800, Volume I, of the Final Report.

4.4.0 FIRST ARTICLE TEST RESULTS FOR PHASE III

As can be inferred from Table 4.3-1, only parts passing Group I test were subjected to further testing, with the exception of parts subjected to Group II test. Hermeticity rejects were subjected to the Group II solderability test, since lead solderability has no relationship to electrical performance. Fifty of each part type passing Group I test were then subjected to the sampling plan outlined in Table 4.3-6 for the various test procedures. All parts going through the test plan outlined in Table 4.3-6 were then delivered in fulfillment of the contract requirement.

TABLE 4.3-6. REVISED MINIMUM SAMPLING REQUIREMENTS FOR PHASE III

	High T Storage/Life Group I, III, IV, V	Shock, Vibration, Thermal Shock and Moisture Resistance Group I, VI	Hermeticity Group I, V
BP-Q	18 (0/1)	24 (2)	8 (0)
BP-LN	18 (0/1)	24 (20)	8 (0)
PC-Q	18 (0/1)	24 (2)	8 (0)
PC-LN	18 (0/1)	24 (2)	8 (0)
TDL-100	9 (0/1)	29 (1)	12 (0)
TDL-200	19 (0/1)	9 (1)	23 (0)

Note: Numbers in parentheses indicate number of defectives allowable.

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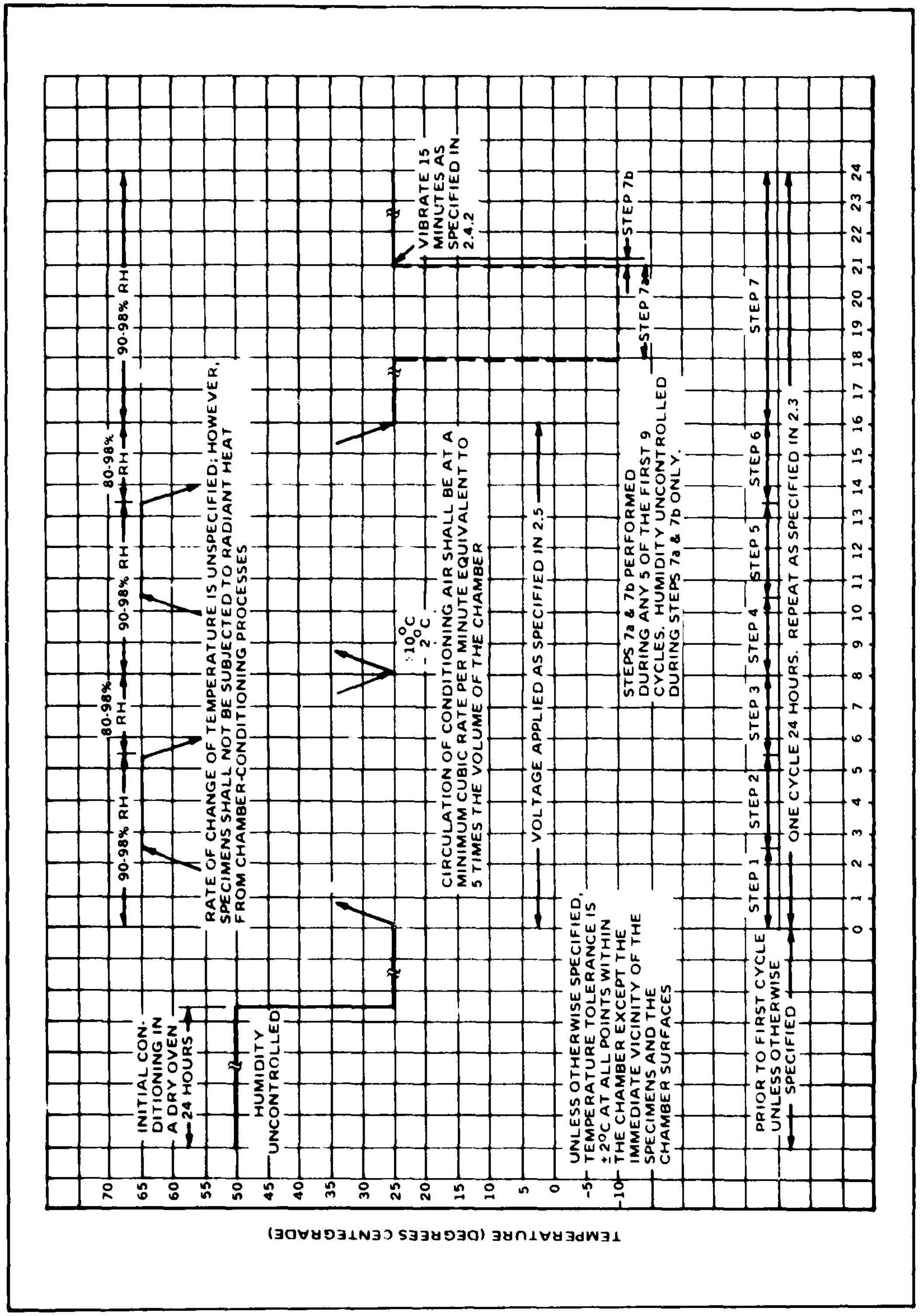

Figure 4.3.4. Graphical Representation of Moisture-Resistance Test

The test sequence to which each individual part was subjected can be seen in Appendix XIII, along with final electrical data taken after the series of tests. Note that β for the TDL and PC devices, τ for the PC devices and $\tau \times \beta$ for the BP and TDL devices was not measured, due to the arguments discussed in Section 3.3.0, Volume 3 of the Final Report. In addition, the VSWR was measured on all devices built during Phase II, Second Engineering Sample Phase. The results were found in general to fall well within the spec limits. However, several Phase II devices failed VSWR between precap and final test. The out of spec condition was attributed to excess RTV dispensed through the center section of the toroid core placed at the device input and output port. The added dielectric material in effect increased the distributed capacitance of the matching network, which in turn, generated the increased mismatch condition.

Based on the observed VSWR test results, and in order to save time and cost, it was decided to perform only pass/reject return loss measurements, as is indicated in Appendix XIII. A summary of failures occurring during first article test can be seen in Table 4.3-7. In all cases, the number of failures experienced was within the limits allowed by the contract.

4.5.0 DISCUSSION OF FAILURES

Table IV of the electrical specification (Appendix IX, Volume III) specified that only insertion loss and center frequency be measured after the non operating, high temperature storage test. In addition, only a short circuit test was specified between the vibration, shock, thermal shock, and moisture resistance tests. Although these tests may be adequate for eliminating failures in active, integrated circuit types of devices, they were inadequate for the device types on this program. As a result, some electrical failures could have occurred during environmental exposures performed earlier in the test sequence. These instances are detailed in the notes for Table 4.3-7. Also, a device failure during the operational tests (life and moisture resistance) could change conditions for the remaining devices on the test board. For the case of operating life test, some devices would experience an increase in power, while others would be subjected to less input power (see Figure 4.3-3). Moisture resistance specimens would see reduced power if a transducer shorted, draining excess current from the constant voltage source and decreasing the output voltage. These facts, coupled with non-performance of failure analyses (they were not required in the contract for First Article Test - see paragraph 4.4.3 of the specification) require a hypothetical discussion of the points of probable failure during First Article Test. Failures will be discussed individually by electrical parameter in the following paragraphs.

Broken Pin - These failures resulted from operator overstress and will not be discussed further.

Insertion Loss - Of the three devices failing from insertion loss in Table 4.3-7, two can definitely be attributed to the operating life test exposure (PC Q, S/N12 and TDL-100, S/N 60). Both devices were sufficiently degraded that insertion loss was not measurable over the dynamic range of the test set (60 dB). The third insertion loss failure (BP Q, S/N 8) occurred during Group VI test, and had a measurable, although grossly

TABLE 4.3-7. PHASE III FIRST ARTICLE TEST FAILURE SUMMARY

	Solderability		High T Storage		3 Life		Hermeticity		Environmental - Group VI				
	Acc No	Group II	Acc No	Group III	Acc No	Group IV	Acc No	Group V	Acc No	Vibration	Shock	Th. Shock	2 Moisture Resistance
BP-Q	0	No Dewetting Failures	0	No Failures Detected For f_o, L_{ins}	1	0	0	Non-Hermetic Devices Were Screened Out	2	No Short Circuit Failures	No Short Circuit Failures	No Short Circuit Failures	S/N 8-L_{IN}, (>20 dB)
BP-LN	0		0		1	0	0		2	See Note 1			S/N 54-S_{sl}
PC-Q	0		0		1	S/N 12-L_{ins} (open)	0		2	No Short Circuit Failures			S/N 67-S_{sl}
PC-LN	0		0		1	S/N 51-S_{sp}	0		2	See Note 1			S/N 20-S_{sp}
TDL-100	0		0		1	S/N 60-L_{ins} (open)	0		1	No Short Circuit Failures			S/N 10-S_{sl}
TDL-200	0		0		1	S/N 94-VSWR	0		1				S/N 55B VSWR

Notes:

1. BP-LN, S/N 75 and PC-LN, S/N 36 incurred broken pins upon installation into the vibration test fixture and could not be electrically tested.

2. Only short circuit testing (specification para. 3.9) was performed after vibration, shock and thermal shock and moisture resistance testing. None of the electrical failures during acceptance test after moisture resitsance exposure would be detected by the short circuit test.

3. Insertion loss and center frequency only were measured between high temperature storage and life test. VSWR and spurious suppression failures could have therefore occurred during high temperature storage.

out of specification, value of insertion loss. It seems reasonable that these failures occurred as a result of the operating and/or DC bias exposure. The failure mechanism could be the result of introduction of a very large series resistance with either transducer, opening of a very large number of fingers, or a very large increase in the sheet resistivity of the metallization. These failures could easily occur if electrolysis occurred between adjacent fingers, resulting in anodization (electrolytic oxidation) of the aluminum metallization. Another failure mode could be galvanic corrosion of the area surrounding the gold wire/aluminum metallization interface. Either of these mechanisms require the presence of an ionically conductive condensate in the area of attack. Although these parts were hermetic, a dry non-volatile atmosphere inside the package is not assured, due to the possibility of outgassing of the RTV or some other organic constituent inside the package. Another possibility is the outgassing of a constituent which chemically attacks the metallization. The TDL devices would be most sensitive to this failure mode, due to the thin metallization (400A). A residual gas analysis of the package atmosphere would have elucidated these failure modes.

Spurious Suppression - All failures occurred after one or more high temperature exposures (PC-LN, S/N 51 and S/N 20). A possible cause of this failure mechanism is densification or delamination of the RTV on the ends of the crystal, thereby changing the acoustic damping coefficient of the absorber. This would result in an increase in end reflections, similar to initial application of an inadequate amount of RTV on the ends of the crystal. It is interesting to note that failure to meet electrical specification was incurred with the PC-LN devices during Phase II of the program (see the discussion on page 3-22, Volume III), and was corrected with addition of RTV.

Sidelobe Suppression - All failures occurred during Group VI testing (PC-Q, S/N 54 and 76; TDL-100, S/N 10). The most probable explanation of these failures is tranducer damage resulting from the same mechanisms discussed in the paragraph on Insertion Loss.

VSWR - Both failures were TDL-200 devices, S/N 94 and 55B. It is likely that the Group VI failure occurred as a result of the thermal cycling exposure resulting from the thermal shock and moisture resistance test. This resulted in mechanical movement of the toroid coils. The high temperature storage/life test failure probably resulted from the detuning of the device, resulting from aging of the toroid core (see Appendix X, Volume III) or the RTV material used to stake the toroid.

4.6.0 CONCLUSIONS FROM PHASE III

Several interpretations of specification requirements were mandated due to inadequacies in the specification. The first of these was the interpretation of "operable" die to be those which met electrical requirements. Experimental data was collected to correlate visual flaws with electrical performance (Table 4.3-4). Lead integrity and bond pull test requirements were unclear, and were interpreted as outlined in Section 4.3.3.2. Life test requirements and procedures were undefined, and were interpreted as outlined in Section 4.3.3.5, with some compromise in Life Test sample size.

Recommendations resulting from Phase III are: use of a complete electrical test rather than the short circuit test between test procedures; derivation of a compromise between equipment cost, test time, and sample size for the life and moisture resistance test, which does not overload some circuits and understress others in the event of device failures during test; and utilization of residual gas analyses using a mass spectrometer for failure analysis of failed devices.

Experimental results of Phase III dictated that number failures did not exceed specified requirements. However, since all parameters were not tested for the high temperature storage test due to inadequacies in specification requirements, thepossibility exists that two failures (PC-LN and TDL-200) may have occurred during this test. Also, the test procedure utilized for the life test essentially reduced the sample which was subjected to "operating" life, and increased the sample subjected to "non-operating" high temperature storage. Normally, a reduction in a sample size using MIL-STD-105 decreases the percentage of failures allowable in a sample for a lot to be acceptable. However, it is impossible to interpret these results using MIL-STD-105, due to the very small sample size.

Finally, it was noted in the interpretation of the experimental results that test conditions utilizing both applied power/voltage and high temperature are more severe for SAW devices than mechanical and non-operating temperature environments.

5.0.0
PILOT LINE IMPLEMENTATION/PRODUCTION (PHASE IV)

5.0.0 PILOT LINE IMPLEMENTATION/PRODUCTION (PHASE IV)

The purpose of Phase IV is the establishment of a pilot production line, consisting of all production and test equipment required to accomplish the pilot production run at the required production rate (150 devices/month). The first part of this segment (5.1.0) will consist of a description of the pilot production line. The second section (5.2.0) will detail the pilot production. This section will include a description of the sampling and test procedures utilized for the pilot production, a presentation of the electrical data, and an analytical section discussing pilot run yields, and device labor and material cost. The third section (5.3.0) will discuss materials and processing considerations for the pilot production, and the last section (5.4.0) will detail conclusions from the pilot production.

5.1.0 PILOT LINE IMPLEMENTATION

This Section will be divided into three subsections discussing the total approach required for pilot line implementation. The space, facilities and manpower will be discussed for the unbalanced production approach utilized for the pilot production. This will be followed by a discussion of the equipment utilized for the pilot production, and its replacement cost. The last discussion will be centered around the capacity of the pilot production line and the bench time required for each operation in the process flow, exclusive of set-up time.

5.1.1 Space, Facilities and Manpower Required for the Pilot Production

Total space required for the pilot production consisted of 900 square feet of on-site laboratory space divided approximately equally into three separate areas, crystal fabrication, header assembly and inspection, and electrical test. In addition, a projection weld sealer was utilized at another Hughes facility as well as a package leak test station, bond-pull station, and marking equipment. These additional stations occupied an additional 200 square feet of laboratory space, making the total requirement 1100 square feet. Space and equipment required for mask making, and environmental test will not be treated here, since capital expense for these items is very high (> $1.0 million). Also, a small business would normally subcontract mask fabrication and environmental test requirements. The philosophy of the MMT program was to establish a base and plans to establish a SAW capability at other sources. Normally, the capital would not be available or warranted in this type of situation to set up a complete environmental lab and/or mask shop.

Facilities required for the pilot production included the following: air conditioning with humidity control; clean rooms and laminar flow work stations; fume exhaust; liquid and gaseous nitrogen, argon; house vacuum lines; city, cooling, and de-ionized water; solvent and acid disposal; and electrical power. All facilities implementation requirements were straight-forward with two exceptions: interaction between the airconditioning system, clean room, and fume exhaust; and the electrical power requirements for the project weld seal station. These two topics will be discussed in

the following paragraphs. A more detailed tabulation of requirements for the individual equipment utilized will be presented in the next section (5.1.2).

As will be discussed in a later section, yields at wafer visual inspection ranged from 56 to 76 percent for the six candidate devices. The majority of the devices ranged yielded from 56 to 70 percent at predice inspection, utilizing the visual inspection criteria outlined in Table 4.3-4. Most of the rejects occurred due to shorts or opens in the active fingers of the transducers. See Figure 5.1.1. After investigating the source of these photolithographic flaws, it was concluded that they were caused by airborne contaminants being introduced on the surface of the crystal before metallization and/or before resist coating. These yields could have been improved substan'ially by a different layout and design of the facility in which the crystals are metallized and photolithographically defined.

The design philosophy of the SAW laboratory was to establish process stations under Class 100 laminar flow stations which were located in a laboratory maintained at positive pressure with respect to entryways in a Class 10,000 condition. The wafer photolithography area was deemed to be most critical, since particulates introduced at this stage of device fabrication manifest themselves as point defects in the transducer pattern i.e., open or shorts [Particulates introduced at later stages of fabrication are non-conductive generally, and can be cleaned off immediately prior to package seal. This laboratory design philosophy would cause problems for very high reliability applications, since SAW devices by their nature cannot be passivated.] Two basic problems existed with the laboratory as it was configured for the pilot production run which make exclusion of airborn particulates impossible. The first problem had to do with the layout of the process line; it was necessary to remove wafers from the Class 100 laminar flow benches and transport them in closed containers between work stations. This could have been corrected by an in-line process, where wafers never leave the Class 100 environment until the pattern is defined. The second, more serious problem is the fume hood design depicted in Figure 5.1-2. This problem relates to the interpretation by the Health and Safety department that an operator at a fume hood must be bathed in fresh air having a velocity of 100 feet per minute across the work surface. In order to accomplish this requirement, facilities engineers set the process sink exhaust dampers such that this air velocity was established downward through the work surface. In order to prevent fumes from entering the laboratory, the flow rate of the HEPA filters was set at 90 feet per minute. The balance of the exhausted air entered the work surface from the laboratory. Fresh, conditioned air was supplied to the plenum above the squirrel cage fan in order to prevent the possibility of fumes which escaped the work surface from being recirculted in the hood area. The plenum was sealed to the conditioned air ductwork and was to be maintained at a pressure less than the laboratory ambient. Disadvantages associated with this clean room design are as follows: 1.) if P_1 exceeds the laboratory ambient air pressure due to clogging of the HEPA filters, raw air will enter the laboratory space; 2.) when other filters on the same ducting system become clogged, the raw air contamination will occur more rapidly; 3.) utilization of laboratory air to bathe the operator causes this raw air to be drawn onto the work surface; 4.) when the HEPA filters become clogged, the laboratory loses positive pressure, since the exhaust system has low resistance and

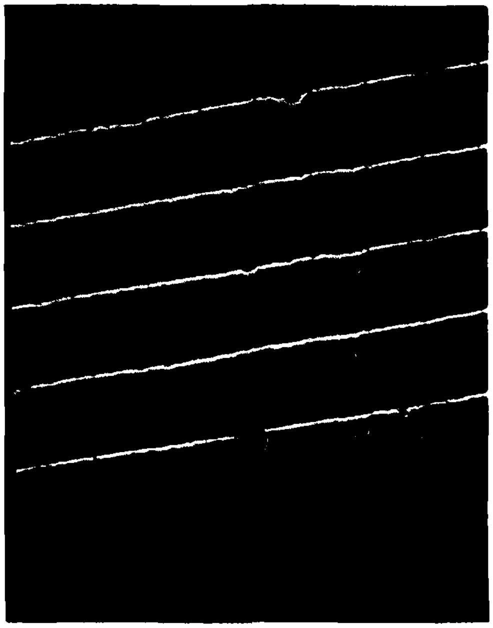

Figure 5.1.1. Micrograph of Open Finger Caused by Particulates on Substrate Surface Prior to Metallization (3000X)

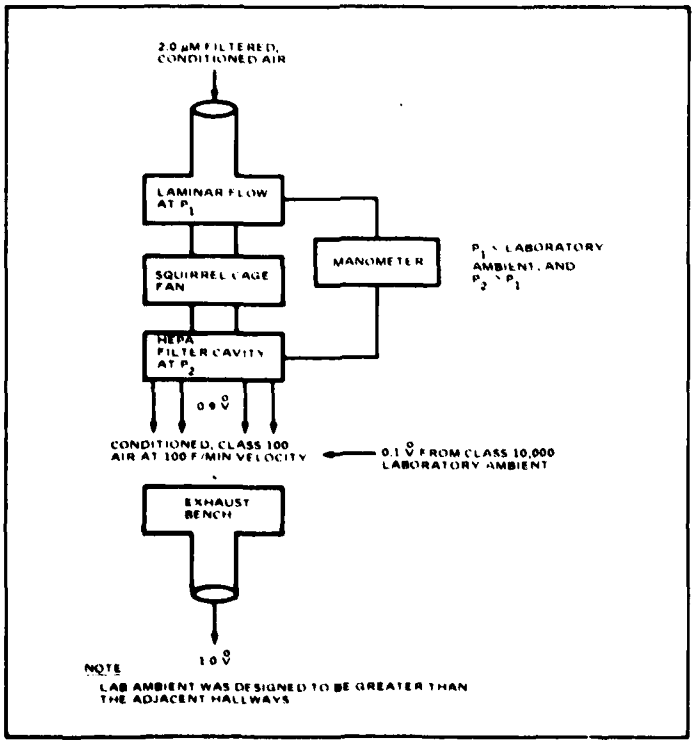

Figure 5.1-2. Schematic of SAW Lab Class 100 Fume Hood Design

will continue to withdraw air from the laboratory at a constant rate; 5.) exhaust and air-conditioning systems of this complexity cannot be balanced properly for any length of time, since there was no feedback of information between the two systems. An additional, although harmless, problem with this design approach is its extreme energy inefficiency, since the conditioned air only enters the laboratory one time before being exhausted through a fume duct. In order to optimize processes for control of photolithographic flaws, it is mandatory to have a clean facility which is totally independent of other laboratories and has a feedback system monitoring exhaust and inlet air flow rates. One particular consultant with a design approach accomplishing these requirements is Environmental Air Control, Inc., Baltimore, Md.

Electrical power requirements for the projection weld seal station utilized on the pilot production were 220 volts/400 ampere service. Initially, the SAW facility was scheduled to obtain this equipment, but capital problems were encountered when facilities planning estimated a $45.0K cost to provide this electrical service. As a result, a projection weld system at another facility was used. This equipment design (Taylor-Winfield) utilized an AC power supply, resulting in the massive power requirement to prevent interference with other equipment on the same line. Currently, Meisser-Greischeim in Germany is manufacturing a capacitor discharge power supply which has very reasonable power requirements, although the initial cost is higher ($55.0Kvs. $40.0K).

Manpower required to staff the SAW facility sufficiently to accomplish the production rate of 150 devices per month was as follows: 2 assemblers, 1 wafer fabricator, 1 test technician, 1 inspector, and 1 supervisor. The supervisor also served in the capacity of production control, and material procurement.

5.1.2 Pilot Line Equipment Requirements

The major equipment required to fabricate the devices for this program is listed in Figure 5.1-3 under the requisite process. As was mentioned earlier, this was not an in-line process, and the various process station depicted in Fiure 5.1-3 utilized much of the same equipment. The detailed equipment required for crystal fabrication can be seen in Table 5.1-1. Those items which were shared or used by more than one process step are designated in the replacement cost column. Facilities required for the individual equipment are listed in the appropriate column. Cost has not been included for the facilities in the replacement cost column of the table. In general, nitrogen, compressed air, de-ionized water, city water, chilled water, and house vacuum would be required to set up a laboratory. The only extraordinary electrical requirement is that power required for the electron beam power supply and associated vacuum chamber. Total replacement cost of the crystal fabrication equipment is $135,978.

Assembly and test requirements depicted in Figure 5.1-3 are tabulated in Table 5.1-2 and 5.1-3. Power to the projection welder was not included in the equipment cost, and was discussed previously in Section 5.1.1. It can be seen that the package seal and leak test stations are major cost

92511-8

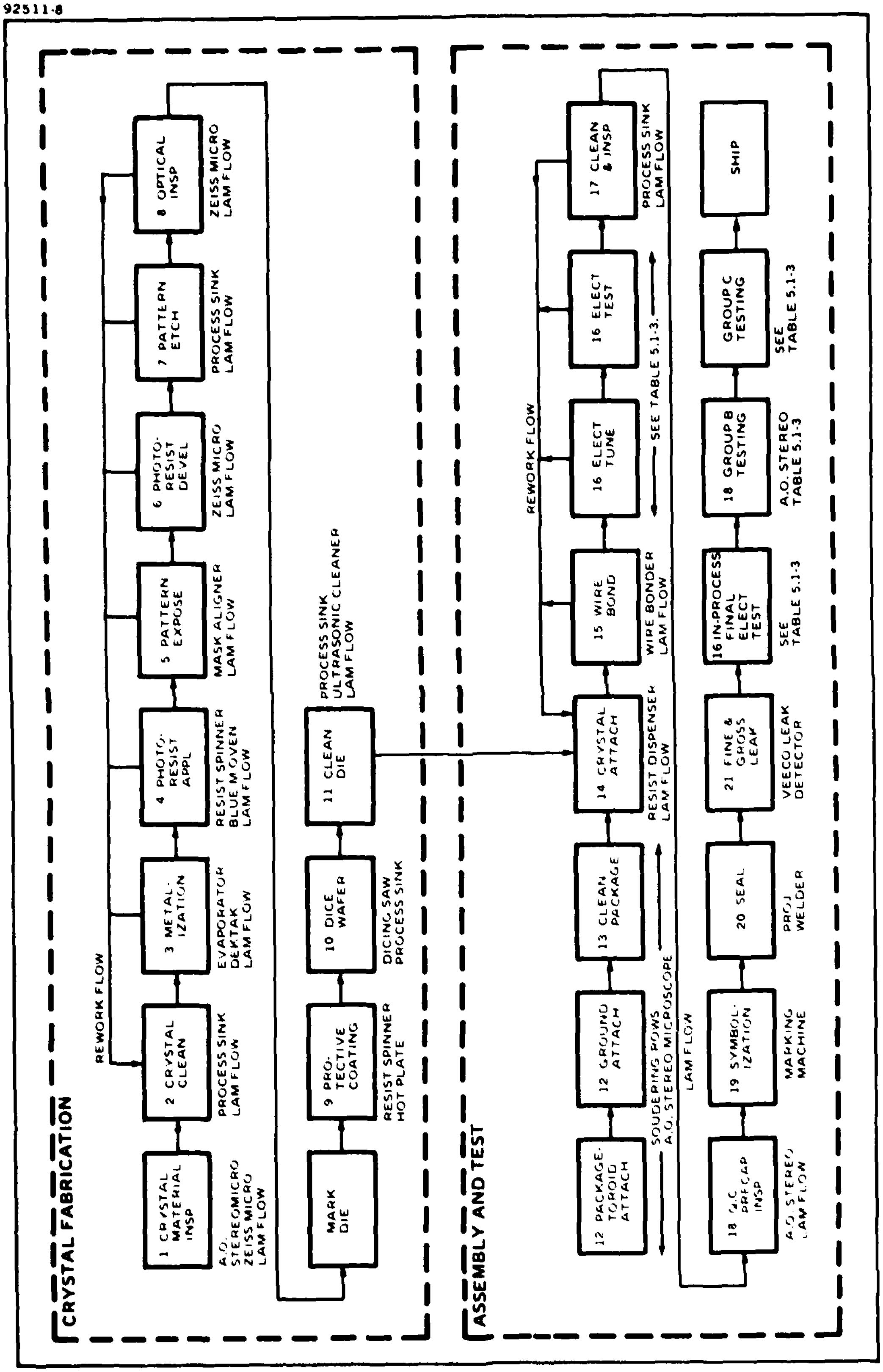

Figure 5.1-3. SAW Device Process Flow with Major Equipment Items

TABLE 5.1-1. CRYSTAL FABRICATION EQUIPMENT AND REPLACEMENT COST

	Qty	Facilities Required	Replacement Cost (10-79)
1. Crystal Substrate Inspection			
a) A.D. Stercostar Zoom #561C-D3	1	110V,5A	846
b) Zeiss Universal Microscope	1	110V,5A	9,612
c) Laminar Flow Station - MicroAir MAA-60/HC-60	1	115V,10A,N,V	1,240
2. Crystal Clean			
a) Petr. Dishes	-	-	200
b) Laminar Flow Station (Same as 1c)	1	Same as 1c	1,740
c) Process sink - MicroAir MBB-80	1	D,N,110V,20A	7,620
d) Ultrasonic Cleaner - Collins Model 50	1		695
3. Metallization			
a) Veeco acuum Chamber	1	Liquid Nitrogen 220V,1Ø,50 amp N,Argon,CW (4 GPM)	10,000
b) Airco Temescal CV8-110 Power Supply	1	220V,3Ø,40A	7,800
c) Electron Beam System - Stih 270-2	1	115V,20A CW (1.25 GPM)	3,150
d) Thickness Measuring Equip	1	115V,20A	10,000
e) Laminar Flow Station (Same as 1c)	1	115V,20A,N,V	1,740
f) Evaporator Controller	1	115V,20A	4,960
4. Photoresist Application			
a) Photoresist Spinner (Platt #103)	1	N,V 110V,7A	2,050
b) Photoresist Dispenser	1	N	500
c) Mechanical Convection Oven	1	115V,20A,N	625
d) Laminar Flow Station	1	Same as 1c	1,740
5. Pattern Exposure			
a) Mask Aligner	1	110V,10A	50,000
b) Laminar Flow Station	1	Same as 1c	Shared w/4

TABLE 5.1-1. CRYSTAL FABRICATION EQUIPMENT AND REPLACEMENT COST (Continued)

	Qty	Facilities Required	Replacement Cost (10-79)
6. Photoresist Development	-	-	Same as 2
7. Pattern Etch	-	-	Same as 2
8. Optical Inspection	-	-	Same as 1
9. Protective Coating Application	-	-	Same as 4
10. Wafer Dicing			
a. Dicing Saw - Electroglass 106	1	110V,7A	15,700
b. Process Sink	1	D,W,CW,V	7,620
c. Hot Plate	1		100
11. Clean Die	-	-	Same as 2
		Total Cost	135,978

N = Nitrogen
A = Air
D = De-ionized Water
O = Oxygen
V = Vacuum
W = Water
CW = Chilled Water
110V,10A,1Ø = Electrical Power

items. Obviously, substantial savings could be achieved in equipment cost if solder sealing were used, but the yields were low for this process at the initiation of the pilot production, and this approach is not recommended. Seal yields will be discussed in a later section. The total replacement cost for the assembly and test equipment is $92,382.

5.1.3 Pilot Line Capacity

One goal of the pilot production was the establishment of the process sequence for each detail part and the determination of the amount of time required to perform each operation in the fabrication sequence. Utilizing the process flow and equipment discussed in Section 5.1.2, the number of hours required to fabricate a wafer were established for the various device types. As can be seen in (Table 5.1-4), the wafer fabrication time for the various device types is the same with the exceptions of removing shorts, visual inspection, dicing, and cleaning. Differences in cost per die result solely from differences in the number of die per wafer. These operations varied as a result of the final die size, number of lines per device, and device line width. When these data are normalized to the device size, as shown

TABLE 5.1-2. ASSEMBLY TEST EQUIPMENT AND REPLACEMENT COST

	Qty	Facilities Required	Replacement Cost (10-79)
12. Toroid and Ground Attach			
a) Soldering Irons	2	110V,5A	500
b) A.O. Stereo Zoom	1	110V,5A	846
c) Laminar Flow Station	1	Same as 1c	1,740
13. Package Clean	-	-	Same as 2
14. Crystal Attach			
a) Resist Dispenser	1	-	1,486
b) Laminar Flow Hood	1	Same as 1c	Shared w/11
15. Wire Bond			
a) Hughes Thermocompression Bonder	1	110V,10A	5,000
b) Bond Pull Tester			
16. Electrical Test			
a) See Table 5.1-3	-	110V,20A	36,226
b) Stereozoom	1	-	846
c) Work Benches	1	-	1,092
17. Clean and Inspect	-	-	Same as 2
18. QC Inspection			
a) AO Stereozoom	1	110V,5A	846
19. Mark	1	110V,10A	1,000
20. Seal			
a) Taylor Winfield Projection Welder with Dry Box and Vacuum Oven	1	220V,400A,1Ø V,A,W,CW	35,000
b) Leak Test			7,800
		Total Cost	92,382

NOTE: Same key for facilities required as Table 5.1-1.

TABLE 5.1-3. ELECTRICAL TEST EQUIPMENT AND REPLACEMENT COST

Instr.	Mfg.	Model	Accuracy	Replacement Cost (10-79)
Oscilloscope	Alfred	8000	2%	7,350
Sweep Network analyzer	Alfred	7051	2%	7,350
Amplifier	Avantek	UTA311N		217
Amplifier	Avantek	UTA311M		217
Amplifier	Avantek	UTA311M		217
Amplifier	Avantek	UTA311M		217
Amplifier	Avantek	AV9-M		1,050
Pulse generator	E-H Research Lab	139B		1,350
Power supply	Hewlett Packard	6215A	3%	155
Power supply	Hewlett Packard	6215A	3%	155
Crystal detector	Hewlett Packard	423A	±0.5 dB	165
Attenuator	Hewlett Packard	355C	±0.25 dB	255
Attenuator	Hewlett Packard	355D	±1.5 dB	255
Attenuator	Hewlett Packard	355C	±0.25 dB	255
Attenuator	Hewlett Packard	355D	±1.5 dB	255
Oscilloscope	Hewlett Packard	183A	3%	2,000
Dual Channel Vert. Amplifier	Hewlett Packard	1830A	3%	1,750
Time Base and Delay Generator	Hewlett Packard	1841A	3%	1,160
Electronic counter	Hewlett Packard	5246L	±1 count	5,300
Frequency converter	Hewlett Packard	5253B	±1 count	1,425
VHF Signal Generator	Hewlett Packard	608D	0.05%	5,800
Oscilloscope	Tektronix	535A	3%	3,800
Dual trace plug in	Tektronix	1A1	3%	3,800
Rho-tector	Telonic	TRB-1	5%	528
Termination	Telonic	TRM-1-1.00F	5%	528
Sweep/Signal Generator	Wavetech	2001	5%	2,350
			Total	36,226

in the device capacity per day column, it becomes readily apparent that the visual inspection and dicing/cleaning operations are the most time consuming and throughput limiting processes.

Similar evaluations were performed for the assembly and electrical test of the various part types. These results can be seen in Table 5.1-5. The only difference among the six device types for these operations is first electrical tune and test. In general, the BP-Q, BP-LN, and PC-Q devices were more tedious to tune than the other part types. These devices had toroids on both input and output ports, requiring tuning for VSWR on both ports due to the lack of reproducibility between toroids. In addition, the insertion loss on the BP-LN device was too low, requiring a scribing operation on the fingers of the MSC to bring the insertion loss into the specification window. It can be seen that the electrical test and die attach/wire bonding operations were the least efficient for these devices. The die

TABLE 5.1-4. CRYSTAL FABRICATION WORK STATION CAPACITY

	BP-Q		BP-LN		PC-Q		PC-LN		TDL-100		TDL-200	
	Hrs Per Wafer	[1]Device Capacity Per Day	Hrs Per Wafer	[1]Device Capacity Per Day	Hrs Per Wafer	Device Capacity Per Day	Hrs Per Wafer	Device Capacity Per Day	Hrs Per Wafer	Device Capacity Per Day	Hrs Per Wafer	Device Capacity Per Day
Clean and Inspect	.2	1073	Same as BP-Q	1040	Same as BP-Q	650	Same as BP-Q	1463	Same as BP-Q	293	Same as BP-Q	390
Metallization	.5	429		416		260		585		117		156
Photoresist Appl.	.1	2145		2080		1300		2925		585		780
Pattern Expose	.5	429		416		260		585		117		156
Photoresist Dev.	.1	2145		2080		1300		2925		585		780
Etch	.3	715		693		433		975		195		260
Remove Shorts	.7	306		297	.5	1300	0	-	.5	117	.5	156
Inspect	1.0	215		208	Same as BP-Q	130	1.5	195	Same as BP-Q	59	Same as BP-Q	78
Thickness Meas.	.1	2145		2080		1300	.1	2925		585		780
Protective Coat	.1	2145		2080		1300	.1	2925		585		780
Dice	1.0	215		208		130	1.5	195	.5	117	.6	130
Clean, Inspect	1.0	215		208		130	1.5	195	.5	117	.5	156

NOTE: [1]Based on an 6.5 hour per day efficiency

TABLE 5.1 5. ASSEMBLY AND TEST WORK STATION CAPACITY

	BP-Q, BP-LN, PC-Q		PC-LN, TDL-100, TDL-200	
	Hrs/Device	[1]Capacity Per Day	Hrs/Device	[1]Capacity Per Day
Pkg Prep	.20	33	.20	33
Die Attach/Wire Bond	.40	17	.40	17
Tune and Test	.50	13	.25	26
Pre cap QC	.10	65	.10	65
Mark	.10	65	.10	65
Seal	.10	65	.10	65
Leak Test	.10	65	.10	65
Final Elect	.25	26	.25	26
Final QC	.10	65	.10	65
Ship	.10	65	.10	65

[1]Based on a 6.5 hour per day efficiency

attach operation efficiency was greatly improved with the use of the RTV dispenser, although very high production rates are required to make the cleaning of this tooling worthwhile. This process could be greatly improved if a disposable dispensing tube, such as that used for epoxy dispensers, could be utilized. Electrical test time would be greatly improved if automated test equipment were implemented. This is possible in the frequency domain with the current generation of network analyzers, such as the Hewlett Packard product line. However, the time domain measurements at this point are not easily automated.

5.2.0 PILOT PRODUCTION

This section will be divided into six subsections detailing all procedures and processes utilized for the pilot production, and data generated from the various tests performed on the devices produced during Phase IV. The first sub-section (5.2.1) will discuss the processes and sampling procedures utilized for Phase IV. This will then be followed by sub-sections discussing precap and final electrical data (5.2.2), Group B and C test data (5.2.3) and a discussion of electrical test data (5.2.4). Yields at the various processing steps in the fabrication process will then be detailed (5.2.5). Total material required for the pilot production and device cost for the pilot production will complete the section (5.2.6 and 5.2.7).

5.2.1 Phase IV Processes and Sampling/Test Plan

Goals of the pilot run were production of the six candidate devices in quantities sufficient to prove and perfect production tools, processes and equipment, and to establish data from which an effective and realistic quality level could be maintained. The production processes utilized for the pilot run have been detailed in Volume I of this report. Section 5.1.0 detailed the equipment, tooling, and processing sequence utilized to accomplish the pilot run. Electrical and environmental test procedures utilized for pilot production were identical to those detailed in Section 4.3.3, with the exception of VSWR data. This parameter was performed on a go-no-go basis per the discussion in Section 4.4.0. The remainder of this subsection will be devoted to the sampling plan and test procedures used to perform quality conformance inspection (Group A, B and C testing) on the devices produced during the pilot run.

For the purposes of this contract, an inspection lot was defined to be all wafers or devices of the same design manufactured sequentially, and utilizing the same processes and procedures. Inspection of the product required for delivery (Quality Conformance Inspection), required completion of Groups A, B, and C testing as summarized in Tables 5.2-1 through 5.2-3. Group A testing was performed on all parts and wafers produced for the pilot run at the process points indicated in Table 4.3-1. Visual inspection criteria for wafers and devices were identical to those utilized during Phase III of the program, and are outlined in Section 4.3.3.1. Note that critical flaws are correlated to actual electrical tests of devices. Due to the high material cost for the SAW crystal ($0.89 to $7.22 for the various device types, unyielded), calculations were made on an individual device basis to determine the number of devices per wafer which were acceptable at photolithographic inspection. The acceptable yields for all devices was thereby determined to be 60 percent. After photolithographic inspection, the wafers were diced and mounted on headers, at which point they were subjected to Subgroup II inspection in Table 5.2-1. Parts passing Group A inspection were then subjected to Group B inspection (Table 5.2-2) to an AQL of 6.5, using the sampling procedure called out for inspection level S-4 and the accept/reject numbers defined in MIL-STD-105. Group C inspection was performed on each lot as detailed in Table 5.2-3, with the exception of the solderability test which was deemed to be inapplicable (since the devices were to be used as a plug-in type of device). In addition, Group C Subgroup I and III tests were performed sequentially on the same sample. The sample size for Group C Subgroup I III testing was six each, and Group C, Subgroup II tests were performed on six devices per inspection lot. Only one failure per group was allowed as the acceptance number. Due to the reduced sample size for the Quality Conformance Inspection testing compared to the First Article Testing, the life test boards were modified to accept three parallel groups of two devices each, rather than the configuration detailed in Figure 4.3-3. This minimized the test affect of the test board as detailed in the discussion in Section 4.3.3.5.

5.2.2 Precap and Final Electrical Data

As can be seen in Figure 5.1-3, cleaned die are attached to a prepared header, wire bonded, and subjected to precap electrical tune and test. Devices which could not be tuned into specification were rejected at this point. A summary of the failures for devices which could not be tuned into specification is detailed in Table 5.2-4. Dash entries indicate no devices exhibiting this failure

TABLE 5.2-1. GROUP A INSPECTION FOR PILOT PRODUCTION

Examination or Test	Requirement Paragraph Appendix IX, Vol 3	Method Paragraph Appendix IX, Vol 3
Subgroup I		
Marking	3.16.1	
Adhesion of metallic film	3.2.1.2	4.6.2
Short circuit	3.9	4.6.8
Visual inspection	3.2.4.1, 3.17	4.6.1
Subgroup II		
Visual (magnification 20X)	3.2.4.2, 3.17	4.6.1.2
Marking	3.16.2	
Hermetic seal	3.6	4.6.5
Strip lead (lead integrity)	3.5.1.2	4.6.4.2
Internal wire bonding (lead integrity)	3.5.2	4.6.4.1

TABLE 5.2-2. GROUP B INSPECTION FOR PILOT PRODUCTION

Examination or Test	Requirement Paragraph Appendix IX, Vol 3	Method Paragraph Appendix IX, Vol 3
Electrical Characteristics		
Center frequency of operation	3.10.1, 3.10.1.1, 3.10.1.2, 3.10.1.3	4.6.9
Bandwidth	3.10.2, 3.10.2.1, 3.10.2.2, 3.10.2.3	4.6.9
Time delay	3.10.3, 3.10.3.1, 3.10.3.2, 3.10.3.3	4.6.9
Time-bandwidth product	3.10.4, 3.10.4.1, 3.10.4.2, 3.10.4.3	4.6.9
Insertion loss	3.10.5, 3.10.5.1, 3.10.5.2, 3.10.5.3	4.6.9
Time-sidelobe suppression level	3.10.6, 3.10.6.1, 3.10.6.2, 3.10.6.3	4.6.9
Feedthrough suppression	3.10.7	4.6.9
Spurious echo suppression	3.10.8	4.6.9
Voltage standing wave ratio (VSWR)	3.10.9	4.6.9

mode, or subsequent tests were not performed after the part failed step following electrical tune and test. Data on devices which could not be tuned into specification was not recorded. Note that the majority of device failures resulted from either insertion loss or VSWR. Devices which were tuned into specification limits were assigned a serial number, electrical data recorded, and toroids ruggedized using RTV. The data for each of the individual devices passing the precap test sequence can be seen in Appendices XIV through XXV by device type.

Following precap visual inspection, all devices were then vacuum baked at 125°C for two hours, transported into a dry nitrogen chamber, and hermetically sealed at atmospheric pressure. [As will be mentioned in Section 5.3.0, a

TABLE 5.2-3. GROUP C INSPECTION FOR PILOT PRODUCTION

Examination or Test	Requirement Paragraph Appendix IX, Vol 3	Test Paragraph Appendix IX, Vol 3
Subgroup I		
High temperature storage	3.11	4.6.10
Short circuit	3.9	4.6.8
Hermetic seal	3.6	4.6.5
Short circuit	3.9	4.6.8
Subgroup II		
Solderability	3.8	4.6.7
Life	3.15	4.6.14
Electrical characteristics	3.10	4.6.9
Subgroup III		
Vibration	3.13	4.6.12
Short circuit	3.9	4.6.8
Shock	3.12	4.6.11
Short circuit	3.9	4.6.8
Thermal shock (10 cycles)	3.7	4.6.6
Short circuit	3.9	4.6.8
Moisture resistance	3.14	4.6.13
Electrical characteristics	3.10	4.6.9

TABLE 5.2-4. PRECAP ELECTRICAL TUNING AND QC INSPECTION REJECTION PERCENTAGES

	BP-Q	BP-LN	PC-Q	PC-LN	TDL-100	TDL-200
f_o	---	---	NA	NA	---	---
β	---	1.2	NA	NA	NA	NA
L_{ins}	0.4	6.6	6.5	2.5	4.8	1.4
S_{sl}	---	3.6	---	---	---	---
S_{ft}	---	---	3.1	1.5	---	1.9
S_{spur}	---	---	2.3	2.5	---	---
VSWR	1.7	10.2	1.5	---	2.2	3.7
Handling Damage	0.4	2.7	3.1	---	0.4	---
Other	---	0.3[1]	---	---	---	---

[1] Toroid damage – tuning.
NA indicates the corresponding test was not performed per rationale detailed in Section 3.3.0.
Shaded area indicates tests performed in the time domain.

change was made during the pilot run from the solder sealing procedure detailed in Section 4.1.0 to a projection welding seal approach.] Parts were then hermetically tested, marked, and subjected to the in-process final electrical test. The in-process final electrical test data on devices passing hermeticity test can be seen in Appendices XIV through XXV by device type. Note that an additional, large percentage of devices failed the in-process final electrical test. These failures are summarized in Table 5.2-5, and were primarily insertion loss and VSWR. Dash entries in the table indicate no devices exhibiting this failure mode, or subsequent tests were not performed after the part failed. The only environments to which these parts had been exposed were the toroid ruggedizing operation (in which the coils of the toroid are potted in RTV), the heating and vacuum exposure associated with hermetic sealing, and the hermeticity test which involves a helium bomb exposure and submersion in 125°C Freon.

5.2.3 Group B and C Test Data

After final electrical test, Group B inspection was performed on parts as they exited in-process final electrical test to sampling level S-4, defined in MIL-STD-105. This test consisted of a duplication of the final electrical test. Samples were drawn on a weekly basis, and were pulled by each device type. All parts were then accumulated until quantities were amassed which were sufficient to meet the delivery requirements of the pilot production. The samples for Group C testing were then pulled (six each for Subgroup II and Subgroup I/III respectively) and subjected to the testing detailed in Table 5.2-3.

TABLE 5.2-5. FINAL ELECTRICAL TEST AND QC INSPECTION REJECTION PERCENTAGES

	BP-Q	BP-LN	PC-Q	PC-LN	TDL-100	TDL-200
f_o	---	---	NA	NA	---	---
β	3.9	2.0	NA	NA	NA	NA
L_{ins}	2.2	1.0	0.6	1.8	1.2	4.4
S_{sl}	---	---	1.2	---	---	---
S_{ft}	---	---	0.6	---	---	---
S_{spur}	---	---	---	0.6	---	---
VSWR	26.1	25.0	2.5[3]	0.6	7.2	9.4
Other	---	---	---	0.6[1] 5.6[2]	---	0.6[2]

[1] Transducer shorted
[2] Pins clipped
[3] Also failed S_{ft} – not counted
NA indicates the corresponding test was not performed per the rationale detailed in Section 3.3.0.
Shaded area indicates tests performed in the time domain.

There were no failures for the samples pulled for Group B testing. However, the Group C electrical data summarized in Appendix XXVI indicates failure of one PC-Q device after exposure to life testing. The failure mode of this device was an output VSWR failure. No other device failures were noted for Group C test. However, substantial changes in some device parameters were noted between the in-process final electrical and post Group C electrical data. A summary of these changes can be seen in Table 5.2-6. VSWR data was not recorded per the discussion in Section 5.2.1. Changes noted in Table 5.2-6 are on the order of measurement error for center frequency, f_o, and bandwidth, β, for all device types (on the order of tenths of a dB and hundredths of a megahertz). However, all parameters measured in the time domain (L_{ins} for TDL-100 and TDL-200; S_{sl} for PC and TDL devices; and S_{ft} and S_{sp} for all device types – see Table 5.2-7) showed substantial changes from one to fourteen dB, with the shift from the initial value occurring in no predictable direction. These drifts are considerably in excess of measurement error, and must be considered indicative changes for the environmental exposures of Group C, Subgroup II and Subgroup I/III testing.

5.2.4 Discussion of Electrical Test Data

As can be seen from Table 5.2-4 the device with the lowest yields at precap electrical test was the BP-LN device. The most predominant failure modes for this device were VSWR and insertion loss. This device required tuning for these parameters by adjusting toroids and scribing MSC lines and/or resistor taps. An analysis of the precap lot date codes in Appendices XIV through XXVI indicates that this device was the first to enter the production line (see Table 5.2-8), and it seems understandable that the technician required considerable learning to establish a tuning procedure. It does appear, however, that the VSWR and insertion loss parameters are consistent loss points for all other device types, although the losses for these parameters are in the range between 0.4 and 10.2 percent. It is not felt that the precap yield losses for the other electrical parameters or visual inspections was excessive for devices of this complexity. Losses for all other reasons combined ranged from 0.4 to 7.8 percent. This is especially true when the design tradeoff between insertion loss and VSWR noted in Volume II of the Final Report is considered.

Although the electrical test yields for precap electricals summarized in Table 5.2-4 are felt to be reasonable, the additional yield losses due to out of specification electrical parameters at final electrical test represented in Table 5.2-5 are felt to be unacceptable. This is especially true for the BP-Q and BP-LN devices, where an additional 25 percent of the parts fell out of specification after exposure to the toroid ruggedizing, vacuum bake, and package seal operation with the associated thermal exposures. (Note that these electrical tests were performed only on the parts passing hermeticity test.) The high losses for the BP-Q and BP-LN devices are explicable in that these were the first devices through the line, and the test technician applied RTV through the center of the toroid core to pot the coils. Although the parts were tuned while the RTV was uncured, the dielectric loss and dielectric constant of the RTV probably changed quite drastically during the curing process. Any thermal exposure would exacerbate this condition. When the RTV was applied to the outside of the toroid coils only on the remainder of the devices for the pilot production, the yield losses due to VSWR at this electrical test can be seen to improve by a factor of two in Table 5.2-5. It can be seen that additional losses were still

TABLE 5.2-6. GROUP C ELECTRICAL DATA SUMMARY

Device	Group	f_o Δ_{ave} (%)	f_o High/Low (MHz)	BW Δ_{ave} (%)	BW High/Low (MHz)	L_{ins} Δ_{ave} (%)	L_{ins} High/Low (dB)	S_{sl} Δ_{ave} (%)	S_{sl} High/Low (dB)	S_{ft} Δ_{ave} (%)	S_{ft} High/Low (dB)	S_{sp} Δ_{ave} (%)	S_{sp} High/Low (dB)
BP-Q	II	0	0 0	-0.3	0 -0.02	-1.2	-0.1 -0.3	0	0 0	-4.8	0 -6	+2.5	0 -2
	I + III	0	0 0	0	+0.01 -0.01	-0.5	0 -0.2	0	0 0	-6.4	0 -10	0	+2 -2
BP-LN	II	0	+0.08 -0.06	-0.2	+0.19 -0.31	0	+0.3 -0.2	0	0 0	+2.1	+6 -5	+5.7	+5 -1
	I + III	0	+0.07 -0.03	+0.1	+0.13 -0.03	0	+0.1 -0.2	0	0 0	+0.8	+3 -4	-1.4	+1 -1
PC-Q	II	NA	NA	NA	NA	0	+0.2 -0.7	-0.1	+1 -1	-1.6	0 -2	+0.9	+2 -1
	I + III	NA	NA	NA	NA	+0.4	+0.7 -0.2	+0.4	+5 -3	+5.5	0 -2	+0.4	+2 -3
PC-LN	II	NA	NA	NA	NA	+0.2	+0.2 -0.1	Leading +55.4 Trailing -7.3	+14 +10 -2 -7	-3.6	-1 -3	+0.5	+3 -1
	I + III	NA	NA	NA	NA	+0.5	+0.3 0	Leading +32.6 Trailing +5.2	+12 +3 +3 -2	-3.1	0 -3	-6.1	0 -4
TDL-100	II	0	0 0	NA	NA	+1.9	0 +1	+0.9	-1 0	+1.1	+3 -3	+5.6	+1 -4
	I + III	0	0 0	NA	NA	-0.1	+2 -2	+1.9	+2 -1	+5.8	+5 +1	-3.0	[illegible]
TDL-200	II	0	0 0	NA	NA	-0.6	0 -1	-2.6	0 -1	-1.2	+2 -3	-4.6	[illegible]
	I + III	0	0 0	NA	NA	+0.1	+1 -2	+1.0	+1 -1	+1.0	+4 -1	+6.7	[illegible] -1

NA indicates parameter was input signal and/or mask dependent, and was therefore not measured per the rationale developed in Section 3.3.0.

TABLE 5.2-7. PILOT PRODUCTION DEVICE TEST SUMMARY MATRIX

Device Type	Electrical Parameter								
	f_o	BW	L_{ins}	S_{sl}	S_{ft}	S_{sp}	VSWR	τ	$\tau \times \beta$
BP-Q	F.D.	F.D.	F.D.	F.D.					
BP-LN	F.D.	F.D.	F.D.	F.D.					
PC-Q	N/A	N/A	F.D.	T.D.	T.D.	T.D.	F.D.	N/A	N/A
PC-LN	N/A	N/A	F.D.	T.D.					
TDL-100	T.D.	N/A	T.D.	T.D.					
TDL-200	T.D.	N/A	T.D.	T.D.					

Key:

F.D. Frequency Domain
T.D. - Time Domain
N/A - Parameter is transmitted signal dependent or is determined by the photomask, and was therefore not measured (see Section 3.3.0)

TABLE 5.2-8. PILOT PRODUCTION LDC SUMMARY

	Precap LDC*	Final LDC*
BP-LN	4/28/77 – 6/5/78	5/5/78 – 7/24/78
BP-Q	8/29/77 – 5/26/78	5/8/78 – 7/26/78
PC-Q	10/14/77 – 6/6/78	12/16/77 – 7/25/78
PC-LN	12/13/77 – 5/17/78	3/24/78 – 7/25/78
TDL-100	11/9/77 – 5/31/78	3/27/78 – 6/8/78
TDL-200	2/17/78 – 6/9/78	3/7/78 – 7/26/78

*LDC = Lot Date Code

incurred at this test point, notably the insertion loss and bandwidth parameter. As can be deduced from the small change in parameter values resulting from the long term thermal exposure of time domain parameters for Group C testing, L_{ins} and β should not be effected by the vacuum bake and package seal/thermal exposure. This drift must therefore be associated with the RTV curing after ruggedizing and/or some other effect resulting from the vacuum bake operation. The changes noted for the time domain tested parameters are understandable in light of the pronounced changes noted in Table 5.2-6 for Group C testing with concomitant thermal exposures.

Group B testing was performed on a sample basis, and is essentially a repeat of the in-process final electrical test, with no intermediate environmental exposure other than ambient laboratory conditions. Since the parts are hermetic, no changes were expected or detected.

The electrical data recorded during Group C testing in Table 5.2-6 is indicative of the device drift during environmental testing. There is no apparent distinction in the percentage change noted for the individual devices between Group II and Group I/III testing. This fact would appear to suggest that the high temperature exposure and applied electrical stress are the factors responsible for device drift, rather than the mechanical and/or thermal shock environment. It should be noted that none of the devices drifted out of specification. However, changes as substantial as the 10 dB decrease in feedthrough suppression for the BP-Q devices would be of concern for some device applications. (A major contribution to changes in feedthrough would be expected from the toroids, due to aging of the core material as outlined in Appendix X, Volume III.) It does appear from the data that parameters most sensitive to thermal exposure were measured in the time domain, since those parameters measured in the frequency domain showed very small changes. This has obvious implications for applications where time domain effects are of importance. An explanation for the pronounced feedthrough suppression changes noted for all device designs is even less tangible when viewed in light of the changes noted for the PC-LN (zero to -3 dB changes from the initial value). This device has no toroids, or discrete tuning elements. Also, the RTV on the crystal ends has no effect on feedthrough suppression. These observations imply that this degradation must be a result of some change in the metallization. Metallization effects would manifest themselves in two ways – changes in sheet resistivity and/or an increase in the acoustic reflections due to the mass loading changes resulting from metallization oxidation. The former would be more pronounced for the thinner metallization devices, although both variations are not independent of one another.

Metallization variations of this nature which occur during thermal aging could also be invoked to explain the changes noted in sidelobe and spurious suppression. Sidelobe suppression changes would be manifested in a manner similar to those changes noted between Phases I and II on the TDL devices (see Section 2.3.2.1, Volume 2). Spurious suppression changes would be made worse due to an increase in triple transit reflections. Another contribution to spurious suppression could result from changes in the RTV during thermal aging, resulting in a reduction in the acoustic absorbance of the RTV with a concomitant increase in end reflections.

Metallization aging effects could be utilized to explain the changes in insertion loss noted for the tap delay lines. An example of this variation of sheet resistivity was the insertion loss drop for the BP-LN devices in Phase III (see Figures 5.2-1 and 5.2-2). The insertion loss for a constant deposition thickness decreased with a decrease in sheet resistivity. Similarly, if the sheet resistivity of the metallization were to increase, the insertion loss would increase, and vice versa. Both increases and decreases in metallization sheet resistivity would be required to explain the insertion loss changes noted for the TDL devices in Table 5.2-6. Metallization sheet resistivity increases are easily explicable by aging phenomena, but decreases are not. These observations, coupled with the lack of an accompanying shift in center frequency for the TDL devices, would indicate that metallization aging phenomena cannot entirely explain the insertion loss drift, although the toroid on these devices could be a contributing factor.

5.2.5 Device Yield Data and Discussion

The Precap and Final electrical yield data summarized in Table 5.2-9 has been presented in Section 5.2.2 and discussed in Section 5.2.4. Device yields at the remaining process steps are detailed in Appendix XXVII and summarized in Table 5.2-9. Shaded areas in the table indicate those process steps where problems were incurred, which will be discussed in the following paragraphs. Roman numerals in the table correspond to those sections in Appendix XXVII. Section 1 consisted of a gross inspection of the wafer at 30X for scratches and macroscopic flaws. Metallization thickness was also measured here, and a 250X magnification inspection of the center and four corners of the wafer for line width control was performed. Unusual problems encountered at this process step were 11% failures on the BP-Q devices due to scratches incurred during the wafer probe experiment which will be discussed in Section 5.3.0. The TDL-100 devices also suffered a 7% rejection of wafers due to overetching, which was incurred as a result of operator training. Section II consisted of an inspection of the individual die on the wafer to the inspection criteria of Table 4.3-4. No peculiarities were noted at this process step other than the opens and shorts incurred as a result of the introduction of particulates onto the surface of the wafer during processing, an example of which was presented in Figure 5.1.1.

Section III of Appendix XXVII consists of the rejections incurred as a result of the dicing operation. Individual die were diced cleaned, and inspected at 250X for chip-outs, metallization scratches incurred in the cleaning operation, and shorts or opens. Excess chipping (14.1% rejects) was noted on the BP-Q devices as a result of the "streets" on the mask being too narrow for the diamond blade width used to dice the wafers. Problems were also incurred with the PC-LN devices due to breakdown of the protective coating of resist on the wafer during the dicing operation. Also, an insoluble residue was found contaminating the surface of some of the PC-LN devices. This material was interpreted to have formed from the adhesive backed tape used to hold the lithium niobate wafers during the dicing operation. A process change in which the lithium niobate wafers were held to the glass backing plate with optical pitch eliminated this problem.

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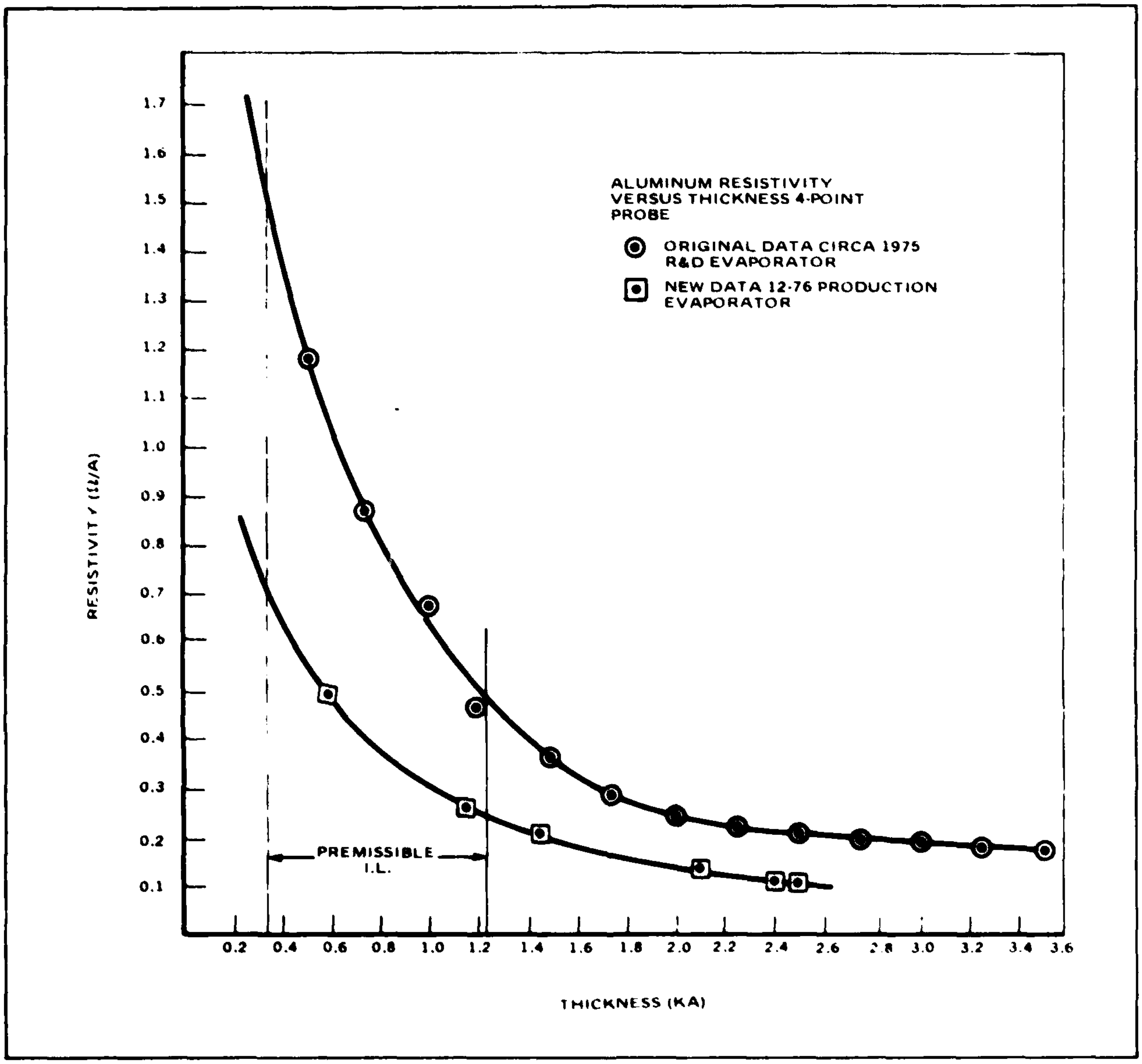

Figure 5.2-1. Resistivity of Electron Beam Evaporated Aluminum

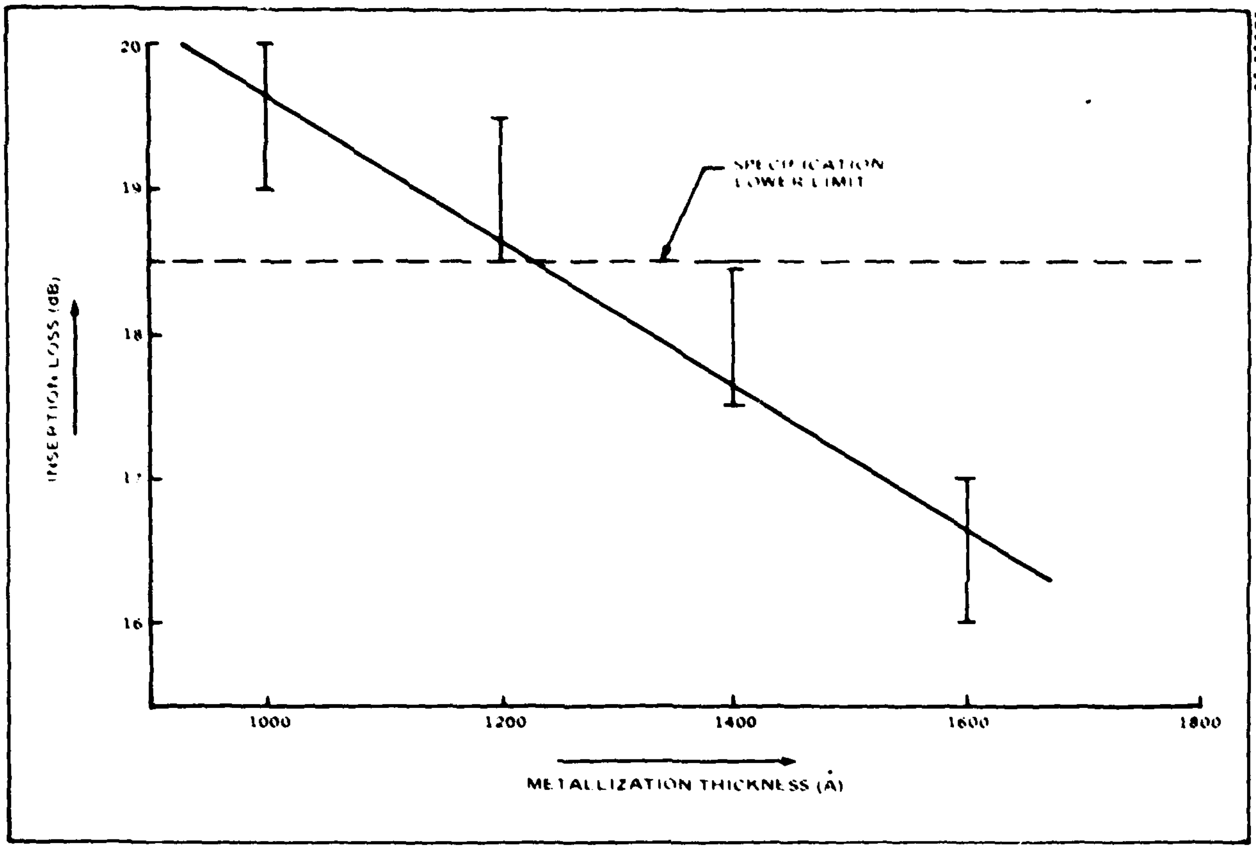

Figure 5.2-2. Insertion Loss as a Function of Metallization Thickness for Pilot Production BP-LN Devices. Error bars indicate the span of measured data for one evaporation run. A 5% average thickness variation was measured across one evaporation run. Measurement accuracy was ± 50 Å, according to the profilometer manufacturer.

TABLE 5.2-9. PILOT PRODUCTION YIELD (%) SUMMARY

Appendix XXVII Designation	Process Description	Device Type					
		BP-Q	BP-LN	PC-Q	PC-LN	TDL-100	TDL-200
I + II	Wafer Photolithography	**56.1**	76.1	71.5	67.3	**69.0**	68.0
III	Post Die Inspection	**72.7**	95.9	91.3	**62.2**	86.9	88.1
IV	Die Mount, Bond	100.0	100.0	**88.0**	95.7	97.8	96.9
-	Package Prep.	90.0	90.0	90.0	90.0	90.0	90.0
V	Precap Electrical	97.5	**75.4**	81.9	91.9	92.5	93.1
VI	Precap QC	94.8	99.2	100.0	100.0	98.6	100.0
VII	Seal, Leak Test	90.0	90.0	**75.1**	88.5	**80.7**	**79.8**
VIII	Final Elect/QC	67.6	71.3	95.6	90.7	91.6	85.6

Section IV consisted of an in-process inspection to the requirements of Appendix XII at 30X. Problems were encountered with the PC-Q devices due to improper mounting of the die on the header (11.8% rejects). This matter was caused by an incorrect mechanical drawing. Package preparation consisted of mounting of the grounding wires, toroids and moly tabs using hand soldering techniques. As was mentioned in Section 3.4.3, Volume III, this was a delicate process which required careful technique on the part of the operator. A ten percent loss was experienced on all header types as a result of wicking of solder on to the top surface of the pin.

Section VI consisted of a QA inspection to the same requirements as Section IV. The only problems encountered here were scratches in the metallization resulting from the tune and test operation. Rejects in this section ran from 0.4 to 1.4 percent.

Section VII suffered numerous failures, the majority of which were hermeticity rejects. The detail of failures at this process step can be seen in Table 5.2.10. The high reject rate of the PC-Q devices was of concern during the pilot run, and caused an evaluation of projection welding to be performed. The header design used for these devices could also be projection welded due to the configuration noted in Figure 4.1-2. As a result, an evaluation of the projection weld sealing of this package was performed with promising results. The balance of the pilot run devices were sealed with this approach. As can be inferred from Table 5.2-10, the reject rate was decreased markedly for this device type. As can be seen in Table 5.2-8, PC-LN devices were fabricated in this same time frame, but the hermeticity reject rate was not changed

TABLE 5.2-10. PERCENTAGE FAILURES AT SEAL, MARK AND LEAK TEST BY FAILURE CATEGORY

	Header Type					
	TF20221				TF20117	
	BP LN	BP-Q	PC-LN	PC-Q	TDL 200	TDL 100
Solder Seal	4.8	3.0	4.9	24.0	20.4	19.3
Proj. Weld	5.2	6.5	3.3	0.5	None	None
Glass Bead		-	3.3	-	-	-
Visual Reject		0.4	-	0.5	-	
Unsealed	0.8	13.4	-	0.9		
Total Loss	10.0	9.9	11.5	25.0	20.4	19.3

drastically by going to this package sealing approach. The BP Q devices had mechanical layouts which were identical to the BP LN and PC Q devices (See Figure 3.2-9, Volume 3). As a result, the only explanation of the higher reject rate for this device type can be failures which resulted from the plating lot for these packages. If the tin plating thickness was insufficient, dewetting would occur locally, causing a hermeticity reject. Note that the TDL headers suffered a similarly high reject rate 20.4 and 19.3 percent, respectively. It would appear that average yields of 95% can be expected from an optimized sealing process. However, the hand soldering approach can be seen to give sporadic results. This fact, when viewed with the high loss at final electrical test for some device types, must be interpreted as a condemnation of the hand soldering approach to package sealing. It should be noted that the reject rates at final electrical test cannot always be correlated with the sealing approach, but a contribution to final electrical failures may be present, due to the high thermal exposure of the hand soldering operation when compared with the projection weld sealing approach. The large package types used on the TDL devices cannot be sealed using projection welding, however. As a result, an alternative approach must be recommended for the large device types, such as seam sealing.

5.2.6 Material Required for the Pilot Production

Using the data in Appendix XXVII, the material required for the pilot production can be seen in Table 5.2-11 by device type. The only item of note here is the doubling of material use incurred for the TDL devices, which obviously relates to the crystal size for these devices when compared with the other device types. Total material for the pilot production of all six device types can be seen in Table 5.2-12.

TABLE 5.2-11. MATERIAL REQUIRED FOR PILOT PRODUCTION BY DEVICE TYPE

	BP-Q	BP-LN	PC-Q	PC-LN	TDL-100	TDL-200
Substrate - ST Quartz	18	-	24	-	43	31
$YZ LiNbO_3$	-	15	-	11	-	-
Header - TF20221	236	333	297	207	-	
TF20117	-	-	-	-	232	223
LID - TF20216	230	249	213	182	-	
TF2011B-175	-	-	-	-	207	201
Input Toroid T16-6	236	333	297	-	232	
T16-10	-	-	-		-	223
Output Toroid - T16-6	236	333	297	-	-	
Moly Tabs	-	-	-	414	-	-

TABLE 5.2-12. TOTAL MATERIAL REQUIRED FOR PILOT PRODUCTION

Material	Quantity	Unit
ST Quartz (substrates)	116	ea
$YZ LiNbO_3$ (substrates)	26	ea
TF20221 (Header)	1,073	ea
TF20216 (Lid)	874	ea
TF20117 (Header)	455	ea
TF20118-175 (Lid)	408	ea
T16-6	1,964	ea
T16-10	223	ea
Moly Tabs	414	ea
Diamond Blades	50	ea
Gold Wire	125	ft
32 AWG Wire	100	ft
Sn63 Solder	2	lbs
Aluminum (99.99%)	500	gms
Acetone	5	gal
Chromic Acid	5	gal
Nitric Acid	5	gal
Phosphoric Acid	5	gal
Alcohol	5	gal

5.2.7 Pilot Production Device Cost

Device yields detailed in Section 5.2.5 and labor per process step detailed in Section 5.1.3 were used as inputs to a reverse cumulative pricing program to calculate the device material and labor costs outlined in Table 5.2-13. Labor and material costs utilized in the program were updated to reflect third quarter, 1979 rates. The costs given in Table 5.2-13 are manufacturing cost level (MCL), and do not include profit, general and administrative, or cost of money expenses. The major cost items for material are packages and crystal substrates. Purchase order costs of the package and die crystal material (i.e. unburdened) are detailed in the table. Die costs were obtained by dividing the third quarter, 1979, wafer cost by the number of die obtainable from one wafer. These unyielded material costs allow the deduction of the cost of material which is lost as a result of process yields. Material costs for the devices ranged from 36% of MCL cost for the BP-LN to 49% of MCL cost for the TDL's. These differences result from the cheaper package of the BP-LN, and the differences in die sizes.

The discussions in Sections 5.2.4 and 5.2.5 imply that the learning which occurred during the pilot production was quite significant. As a result, the labor and material cost which was incurred during the pilot production was higher than that which would be experienced for long production runs of one device type -- one to two thousand parts rather than the 150 quantity built for the pilot production. Using the assumed improvements in yields outlined in Table 5.2.14, device costs were recalculated using the same labor rates and material costs. MCL cost improvements ranged from $6.92 for the PC-LN to $44.88 for the BP-Q. Larger production runs would have an additional cost savings resulting from large volume procurement. This savings is estimated to range from 10% of the improved MCL for the BP-Q devices to 13% of the improved MCL for the TDL devices, yielding an anticipated device MCL cost from $79.68 for the BP-Q to $115.25 for the TDL-200.

5.3.0 MATERIALS AND PROCESSING CONSIDERATIONS

This section will be divided into four segments. The first will discuss differences in the sheet resistivity of aluminum films deposited in two different evaporators and its effect on electrical parameters. The second subsection will detail analyses performed to elucidate changes noted between precap and final electrical data. The third will discuss tradeoffs encountered in the change of package sealing processes. Subsection four will detail the capacitance probe evaluation which was performed to determine feasibility of elimination of the visual inspection.

5.3.1 As-Deposited Metallization Resistivity Differences

It was noted in Figures 5.2.1 and 5.2.2 that different sheet resistivities were obtained for the same thickness deposited film between the evaporators in the prototype and production areas. The prototype evaporator did not use a rate monitor during the metallization deposition.

TABLE 5.2-13. COST SUMMARY FOR PILOT RUN AND YIELD IMPROVEMENTS

Cost Description	BP-Q		BP-LN		PC-Q		PC-LN		TDL-100		TDL-200	
	Pilot Run	Process Imp	Pilot Run	Process Imp	Pilot Run	Process Imp	Pilot Run	Process Imp	Pilot Run	Process Imp	Pilot Run	Process Imp
Yielded Labor	$ 74.83	$ 49.66	$ 85.90	$ 61.92	$ 76.98	$ 63.42	$ 54.71	$ 51.26	$ 75.44	$ 61.72	$ 73.79	$ 58.47
Yielded Material	53.07	33.36	48.61	37.75	49.20	41.75	39.21	35.74	73.44	63.74	72.23	65.27
MCL Total	127.90	83.02 (44.88)	133.80	99.67 (34.13)	126.18	105.17 (21.01)	93.92	87.00 (6.92)	148.88	125.46 (23.42)	146.02	123.74 (22.28)
Material Percent of MCL Total	41%	40%	36%	38%	39%	40%	42%	41%	49%	51%	49%	53%
Unyielded Package	$ 22.00	N/A	$ 22.00	N/A	$ 22.00	N/A	$ 22.00	N/A	$ 29.68	N/A	$ 29.68	N/A
Unyielded Die	1.96	N/A	1.25	N/A	3.25	N/A	0.89	N/A	7.22	N/A	5.42	N/A

NOTES:

1. BP-LN VSWR was marginal with respect to insertion loss, resulting in lower first electrical yields.
2. BP-Q, PC-Q and PC-LN mask "Streets" were too narrow for the dicing blade used, resulting in lower post dice inspection yields.
3. Process Improvements column assumes yield and process improvements resulting from optimized processes for each part type and long production runs.
4. Yielded material cost could be reduced by approximately 25 percent, or $12 to $15, by large volume procurement of packages and wafers.
5. Numbers in parentheses indicate the MCL cost difference between the Pilot Production and Process Improvements columns.

TABLE 5.2-14. YIELD CHANGES UTILIZED TO CALCULATE IMPROVED DEVICE COST

Device Type	Process Step	Pilot Production Yields (%)	Improved Yields (%)
BP-Q	Final Electrical	68	97
	Seal	61	97
	Wafer Yield	37	59
BP-LN	Wafer Inspection	75	85
	Final Electrical	71	90
	Wafer Yield	44	58
	Seal	63	81
PC-Q	Tune & Test	82	85
	Leak Test	74	85
	Wafer Yield	40.8	53
	Wafer Inspection	72	75
	PR Coat/Mount	90	95
	Seal	72	83
PC-LN	Wafer Yield	33	47
	Wafer Inspection	67	75
	Metal Thickness	82	95
TDL-100	Leak Test	80	85
	Wafer Yield	37.4	52
	Wafer Inspection	69	75
	Metal Thickness	90	100
	Die Clean	86	91
	Seal	73	98
TDL-200	Wafer Inspection	68	75
	Metal Thickness	90	95
	Die Clean	88	91
	Seal	68	78

As a result the evaporation rate is unknown, and probably varies during the deposition cycle. The approach used in the production area made use of an Imficon XMS-1 deposition controller, which allows the programming of the parameters outlined in Figure 5.3-1. The control of deposition rate allows control of the amount of oxygen incorporated into the film, with subsequent control of the film sheet resistivity. The deposition rate differences probably accoounted for the sheet resistivity variations. Note in Figure 5.2-1 that the thinner film sheet resistivities (less than 1,000 A) for the production evaporator using the Imficon controller are easier to control due to the lower slope of the resistivity vs thickness curve. This would have the effect of narrowing the error bands in Figure 5.2.2 for a constant metallization thickness. An additional contribution to the resistivity changes in the prorotype evaporator would result from

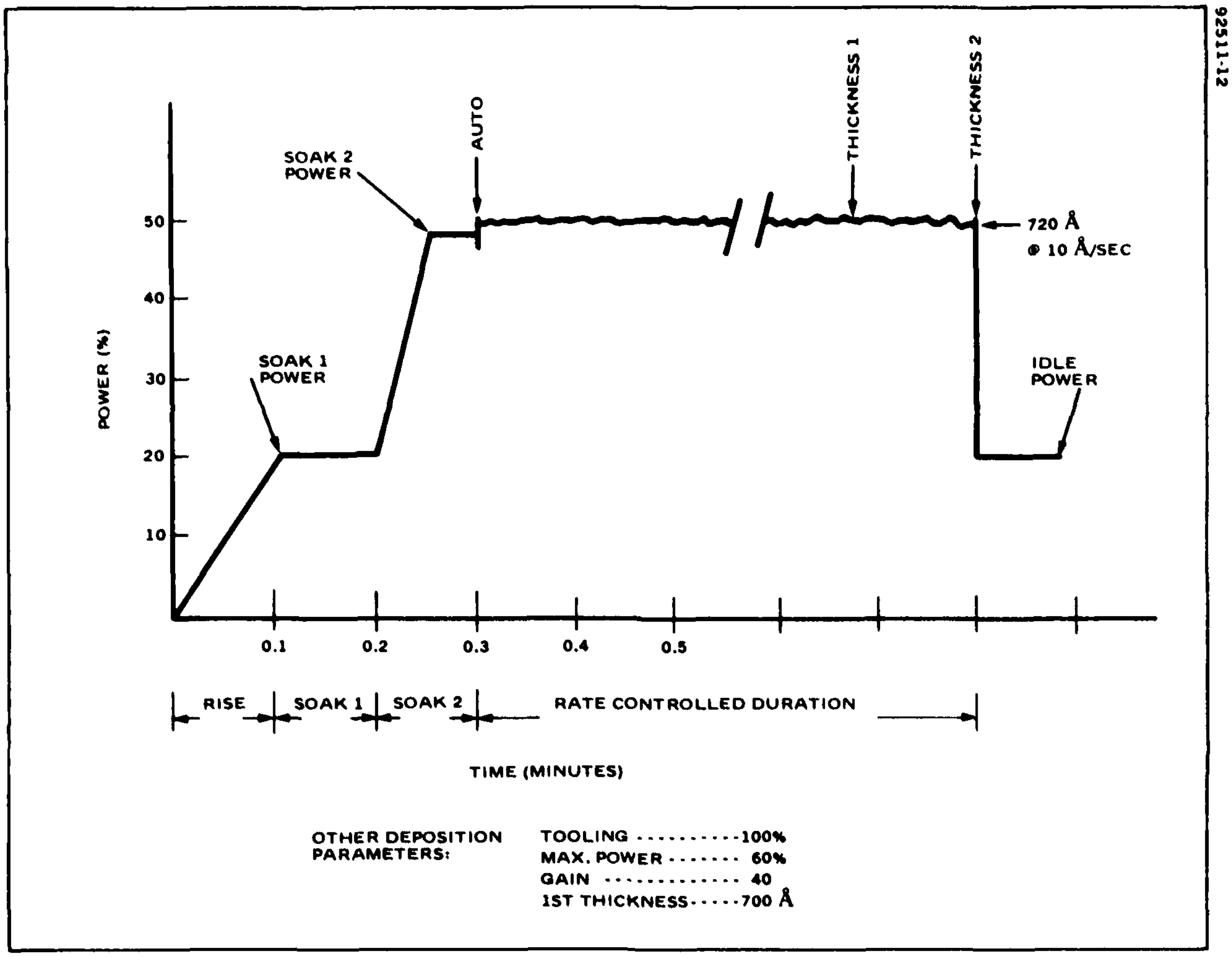

Figure 5.3-1. Sample Deposition Run

the fact that the evaporator was not pumped continuously. This would have the effect of increasing the background oxygen partial pressure during deposition due to the walls of the vacuum chamber outgassing, which would degrade the situation depicted in Figure 5.2-1.

5.3.2 Precap/Final Electrical Test Failures

In order to understand the dropout of devices between Precap and Final electrical test detailed in Section 5.2.4, a residual gas analysis was performed on two devices using Method 1018 of Mil Std 883B. This type of test places the part to be analyzed in a vacuum chamber maintained at 100°C. The package is ruptured with a needle attached to a vacuum feedthrough, and the internal atmosphere vented into a mass spectrometer through a fixed orifice. A mass scan is then performed over the 1 to 500 amu range. Analysis of the spectra is then performed and the internal atmosphere interpreted. No unusual contaminants were detected in the devices tested, indicating that the electrical changes noted in section 5.2.4 must result from aging of the toroids or metallization rather than contamination of the transducers from some outgassing element in the package.

5.3.3 Package Sealing

Low hermeticity yields detailed in Figure 5.2-10 caused an examination of alternative sealing procedures other than the hand soldering approach. Since the Tekform 20221 header had been designed for projection welding or solder sealing, the projection welder approach had the benefit of not requiring a package redesign, with a reorder of packages quoted to be sixteen weeks. Projection weld package designs were depicted schematically in Figure 4.1-2. This technique utilizes the electrodes depicted in Figure 5.3-2. These electrodes are mounted in a hydraulic ram which compresses the weld projection into the lid. Once the initial pressure is applied (nominally 500 pounds force per lineal inch of seal perimeter), a current pulse is applied to preheat the weld area. The weld pulse is then applied which is nominally 50 kiloamperes for 50 milliseconds. During the weld time the projection and lid become molten in the area of contact. The ram is maintaining a constant force on the electrodes, and this causes the molten material to be expelled from the interface area. Cross sections of typical packages can be seen in Figure 5.3-3. Note the expelled material. If the ram force is too high, the entire projection collapses and/or weld splatter is created internal to the package. The situation in Figure 5.3-3 is ideal from a weld schedule standpoint. Expulsion was a problem on the solder plated packages, and some shorted parts were found after the sealing process. Packages were available from another program which were gold plated, and the problem diminished. The weld schedule used for this package can be seen in Figure 5.3-4. A review of the schedule development procedures has been published by J. W. Denison of Martin Marietta.[1] Another problem with projection

[1] J.W. Denison, "Projection Weld Sealing of Microcircuit Packages", Electronic Packaging and Production, July, 1973, pp. 66-82.

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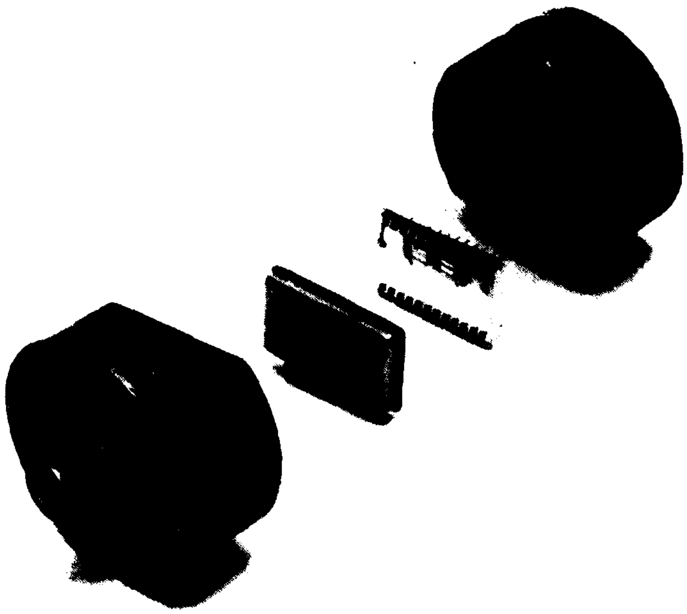
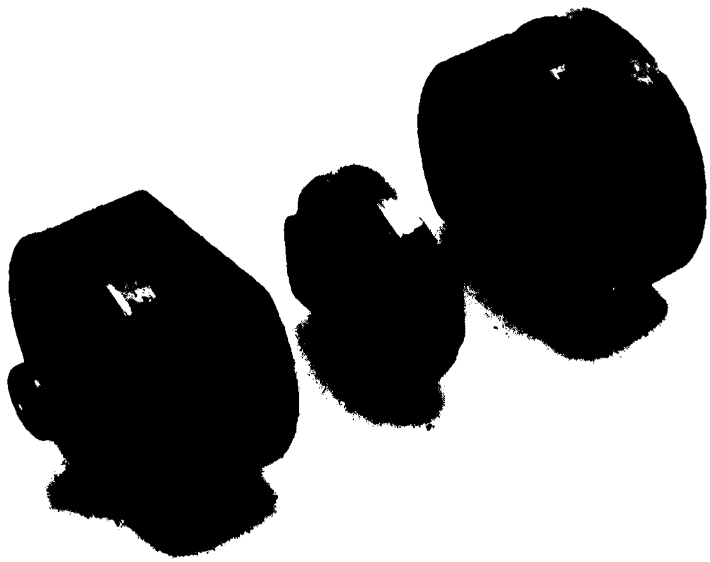


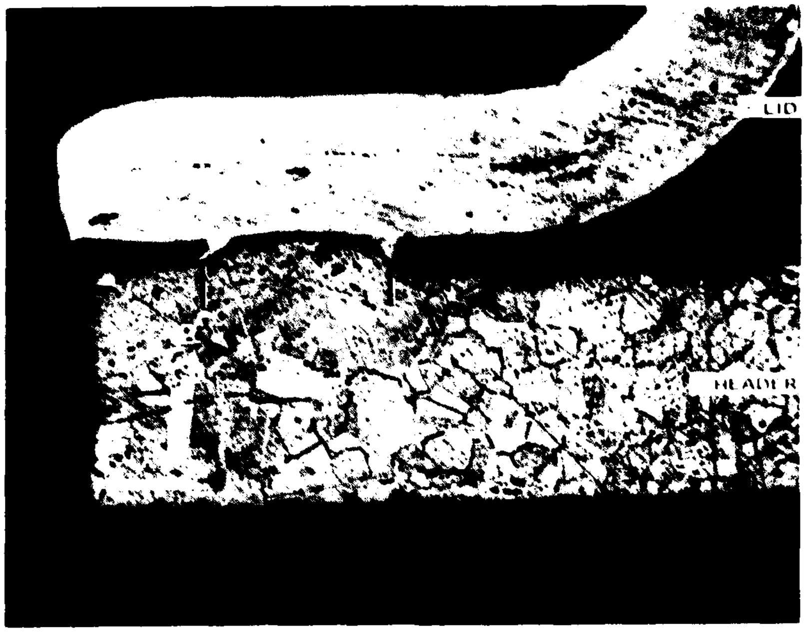
Electrodes With Alignment Tool in Perspective

80-01-390



Electrodes With Header and Lid in Perspective

Figure 5.3-2. Photograph of Projection Weld Electrodes Utilized to Seal the TEKFORM 20221 Header



CROSS SECTION OF WELD AREA ON A TF20221 PACKAGE. RAM FORCE = 1600 LBS, HEAT SETTING 95%, TAP 3, HIGH POSITION. 75X.

HIGH MAGNIFICATION OF AREAS INDICATED BY ARROWS. 275X.

Figure 5.3.3. Cross Section of the Projection Weld Area on a TEKFORM 20221 Package

HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

GEAR NO.	MICROCIRCUIT PACKAGE SEALING/ RESISTANCE WELD SCHEDULE NO.	SHOP ORDER NO.
PC-112	1	N/A

PACKAGE TYPE	PACKAGE DRAWING NO.	DATE / TIME
24 Pin DDIP	300H002	DATE: 5-15-73 TIME: 3:00 PM

PACKAGE	LID	HEADER	Internal Volume
Material	Nickel	Kovar (Au)	1.1 cc
Drawing No.	300H003	300H002	
Vendor	Tekform	Tekform	

OPERATOR	E. Greives
SUPERVISOR	M O Samuelson
PROCESS Q.C. ENGINEER	J K White
ADV. MFG. TECH. ENGR.	M O Samuelson

ELECTRODES	UPPER	LOWER
Part No.	SK-150-11 Rev A	SK-150-9 Rev A
Material	RWMA-CL2 Cu	RWMA CL3 Cu

WELD SCHEDULE SETTINGS

Parameters	Machine Settings	
Transformer Tap	3	Tap No.
PG-1	12	PSIG
PG-2	50	PSIG
Weld Force	1000	lbs.
Transformer Winding	Parallel	Winding
	Electronic Control Settings	
Half Cycle	Off	Position
Heat Control	50	%
Weld No Weld	Weld	Position
Repeat Non Repeat	Non-Repeat	Position
[illegible]	Off	Position
[illegible]	2	Cycles
Initial [illegible]	60	
Squeeze Time	50	Cycles
Weld Time	3	Cycles
Hold Time	50	Cycles
Off Time	N/A	Cycles

MACHINE DATA

Company	TAYLOR-WINFIELD
Address	WARREN, OHIO
Serial No.	0077
Type	AC Resistance Welder
Rated Capacity	100 KVA

REMARKS:

PACKAGE LEAK TEST RESULTS**

UNIT NO.	FINE* LRN	FINE* MEAS. (HELIUM)	FINE* CALC. (AIR)	GROSS STEP #1	GROSS STEP #2
1	0.7	4.2×10^{-7}	4.2×10^{-8}	OK	OK
2	0.7	"	"	OK	OK
3	0.7	"	"	OK	OK
4	0.7	"	"	OK	OK
5	0.8	4.8×10^{-7}	4.8×10^{-8}	OK	OK
6	0.9	5.4×10^{-7}	5.4×10^{-8}	OK	OK
7	0.6	3.6×10^{-7}	3.6×10^{-8}	OK	OK
8	0.9	5.4×10^{-7}	5.4×10^{-8}	OK	OK
9	0.52	3.1×10^{-7}	3.1×10^{-8}	OK	OK
10	0.8	4.8×10^{-7}	4.8×10^{-8}	OK	OK
11	0.52	3.1×10^{-7}	3.1×10^{-8}	OK	OK
12	0.6	3.6×10^{-7}	3.6×10^{-8}	OK	OK
13	0.6	"	"	OK	OK
14	1.0	6.0×10^{-7}	[illegible]	OK	OK
15	0.9	5.4×10^{-7}	5.4×10^{-8}	OK	OK
16	0.9	"	"	OK	OK
17	0.84	5.0×10^{-7}	5.0×10^{-8}	OK	OK
18	0.8	4.8×10^{-7}	4.8×10^{-8}	OK	OK
19	0.74	4.4×10^{-7}	4.4×10^{-8}	OK	OK
20	0.74	"	"	OK	OK
21	0.72	4.3×10^{-7}	4.3×10^{-8}	OK	OK
22	0.62	3.7×10^{-7}	3.7×10^{-8}	OK	OK
23	0.62	"	"	OK	OK
24	0.6	3.6×10^{-7}	3.6×10^{-8}	OK	OK
25	0.56	[illegible]	[illegible]	OK	OK
STD					

CERTIFIED

LEAK TEST INFORMATION

MAXIMUM LEAK RATE* MEASURED (HELIUM)	MAXIMUM LEAK RATE* CALCULATED (AIR)	CALIBRATION		
5×10^{-7} cc/sec	5×10^{-6} cc/sec	Bombing/Backfill Gas	Helium	
		Bombing Time	26	Minutes
		Bombing Pressure	50	PSIG
		Dwell Time	5 to 30	Minutes
		Std. Calibrated Leak	1.1×10^{-8}	*
		Measured Leak Rate Std.	1.3	
		Test System Sensitivity	1.2×10^{-10}	*
		Mass Spec. Serial No.	633	

*ATM - CC/Sec. ** Per Method 1014, MIL-STD-883

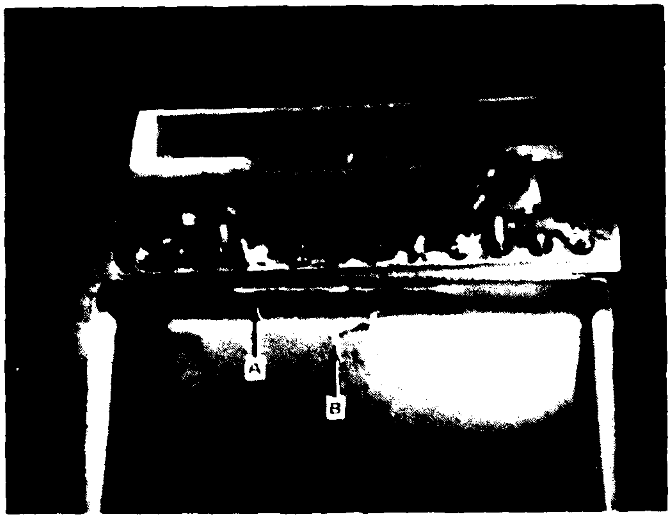
FIGURE 5.3-4 WELD SCHEDULE AND CERTIFICATION DATA FOR TEKFORM 20221 PACKAGE.

welded hermeticity failures was encountered on the pilot production. Upon decapping the failed parts, solder was noted on the package lid in the vicinity of the leak area. See Figure 5.3-5. Since the lid does not see temperatures high enough to reflow solder normally, it appears that the wire used to ground the pin came into contact with the lid during the package sealing cycle. The soldered lead served as a current shunt, causing cold welding in the area and launching solder into the package cavity. The soldered lead was excluded from the seal area, and the problem disappeared. Sealing yields for the projection welded package were typically 95% after the initial problems were resolved. It should be noted that a device for another program had a soldered toroid lead/pad interface which was floating with respect to ground, and was in close proximity to the lid. This solder joint was reflowing during the seal operation. The cause is not understood at this time, since the voltage is very low in a projection weld cycle. However, current application rates of 10^6 amperes/second can induce substantial eddy currents in the package which might cause the toroid to act as the secondary element in a transformer producing field strengths high enough to arc to the package walls. Impingement of the arc on the soldered pad would cause the reflow noted. Grounding of the input pin during sealing should cure this problem. It should also be noted that the use of septums in this type of package can cause similar current shunting problems with concomitant low hermeticity yields.

As was mentioned in Section 5.1.1, a survey was made to determine the cost of installing a projection welder. A breakdown of some of the tradeoffs involved with the various sealing equipment can be seen in Table 5.3-1.

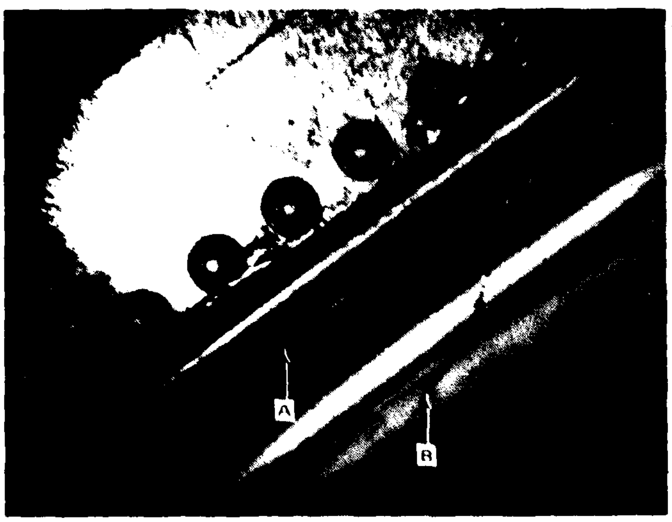
5.3.4 Capacitance Probing of Wafers

A modification of the contract was generated in October, 1976, to explore the feasibility of replacing the wafer visual inspection by an automated probing procedure. Operational tests were felt to be unfavorable because of the requirement to tailor a test procedure for each device type. In addition, insertion loss variations due to probe contact resistance, and anomalies resulting from the high feedthrough due to the probe card were felt to be detrimental to this approach. It was felt that the approach detailed in Figure 5.3-6 showed promise. The program in Appendix XXVIII was generated to drive an Electroglass automated probe station which interfaced with a Fairchild Sentry 610 system. Representative wafers of BP-Q and BP-LN devices were probed using this approach. The capacitance data can be seen in Appendices XIX and XXX. After the probing operation was complete, the devices were visually inspected to the requirements of Table 4.3-4. These requirements had previously been determined to correlate with electrical failures. Typical data can be seen in Table 5.3-2 for a BP-Q wafer. The shaded areas indicate either visual rejectable die per Table 4.3-4, or capacitance probe failures. The failure modes are summarized in Table 5.3-3.



92511-17

TF 20221 HEADER SHOWING SOLDER SPLATTER RESULTING FROM LID SEALING OPERATION



92511-18

HIGHER MAGNIFICATION OF SOLDER SPLATTER AREA

Figure 5.3-5.

TABLE 5.3-1. COMPARATIVE COSTS/SPECIFICATIONS

	Resistance Welders		Fusion Welding Techniques			
			TIG		e-Beam	
	Seam	Projection	Pulsed	D.C.	Pulsed	D.C.
Vendor	ssec	Taylor Winfield	Dimetrics	CPI	EBW 300	
Capital Cost New [3]	$16.5K	$40K	$6K	$15K	$68K	
Size High	18 in.	82 in.	18 in.	42 in.	68 in.	
Size Wide	18 in.	60 in.	18 in.	36 in.	80 in.	
Size Deep	24 in.	55 in.	24 in.	36 in.	57 in.	
Weight	100	5,000	50	500	3,500	
Cooling Water	None	6 gpm @ 20 psi 60°F	None	None	2 gpm @ 20 psi 70°F max	
Air	80 psi	80 psi	None	None	80-125 psi	
Input Power	110V 1φ 60 Hz 30A	208V 1φ 60 Hz 400A	110V 1φ 60 Hz 20A	220V 3φ 60 Hz 30A/	240V 3φ 60 Hz 25A/	
Output Power Open Circuit -V-	80V	60V	-80V	60V	60 kV	
Output Power Max Current	1000A	96,000A	70A	100A	50 mA	
Output Power Max Power	2.0 kW	1,200 kW	1.4 kW	2.0 kW	3,000 kW	
Tooling Cost/Pkg Type	$230	$325	Note 2	Note 2	Note 2	
Max. Seal Length (Kovar)	2 in. x 2 in.	7 lineal in.	No Limit [1]	No Limit [1]	No Limit [1]	
Turnaround/Cycle	2 min	2 min	5 min	5 min	90 min [4]	
Max. No. Parts/Cycle	1	1	1	1	12	
Total Package Energy Input for Typical Sealing Schedule	1,200 J/in. [6]	8,400 J/in. [5]	200 J/in.	800 J/in.	100 J/in.	

1. Seal size limitations of these techniques are limited by tooling to maintain mechanical tolerances. EBW should be the best, due to the beam depth of focus.
2. Cost for a microcomputer controlled tool which would handle all package aspect ratios will be $20K.
3. Does not include dry box, vacuum oven or similar peripherals.
4. EBW vacuum bake must be integrated into turnaround cycle.
5. Projection welded packages are surrounded by massive heat sinks (tooling) held to the package with 4,300 lb force during welding. Therefore comparison of energy inputs with fusion welding techniques is impossible.
6. Recommended schedule for lid weld from SSEC.

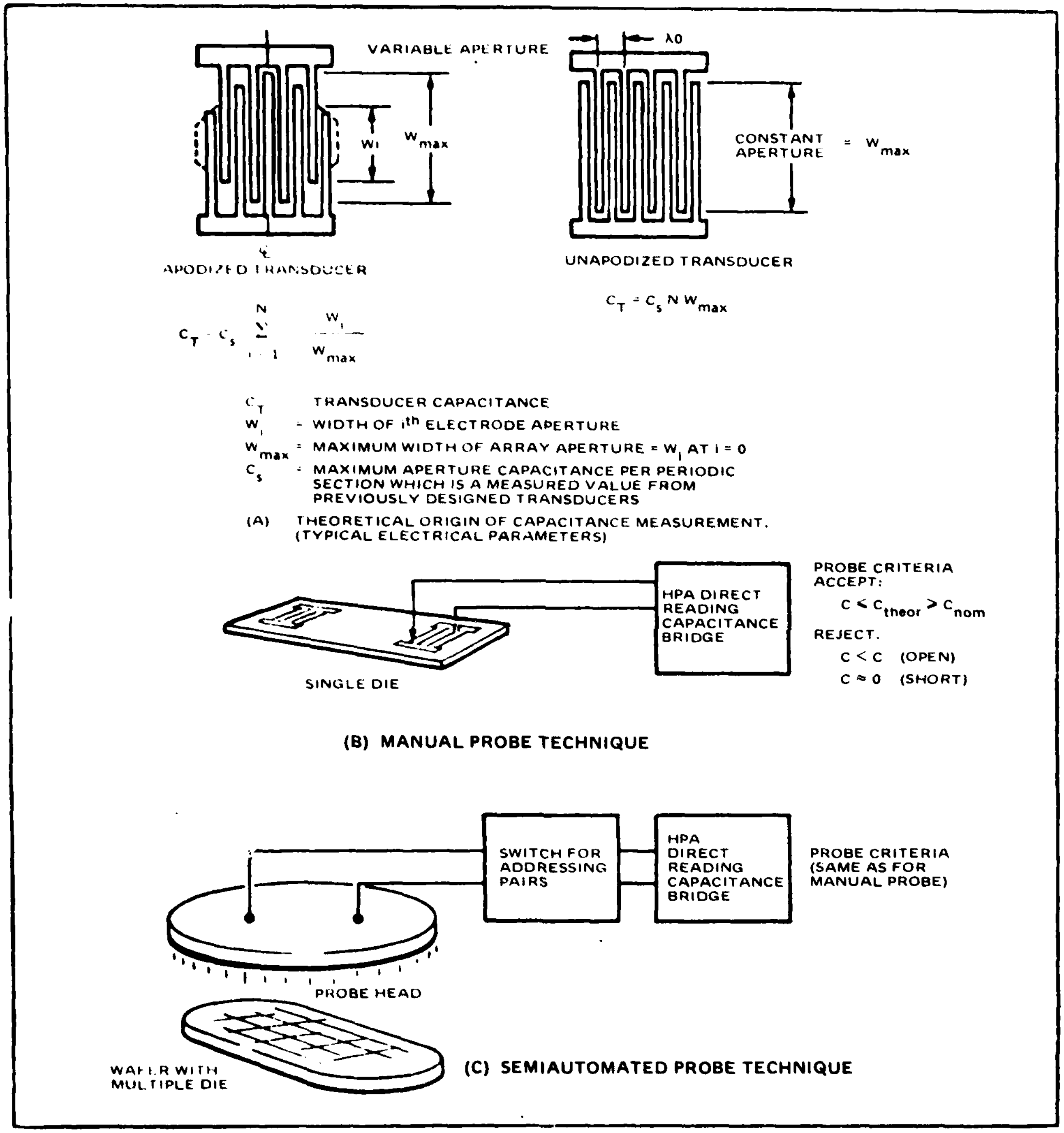


Figure 5.3-6. Capacitance Probe Measurement Test Schematic

TABLE 5.3-2. WAFER #6, LOT 51 BP-Q

Column	1 Input	1 Output	2 Input	2 Output	3 Input	3 Output
Row 1	6.68 3-0	5.71 X	1.49 S	1.47 X	1.40 1-0	1.28 1/2-0
2	8.30 1/2-0	6.75 2-1/2-0	8.03 2-0	6.69 5-0	8.31 1/2-0	6.23 1/2-0
3	8.21 1/2-0	6.56 1/2-0	8.14 6-0	6.69 2-1/2-0	8.20 1-1/2-0	6.27 1/2-0
4	8.20 2-0	99.89 S	8.28 X	6.53 2-0	8.15 1-1/2-0	8.02 3-1/2-0
5	8.15 1/2-0	6.58 4-1/2-0	8.17 4-0	6.46 1/2-0	7.92 3-1/2-0	99.89 S
6	7.97 6-1/2-0	6.54 1-0	8.12 X	6.40 3-1/2-0	7.12 X	6.18 X
7	8.22 1-1/2-0	6.55 3-0	8.13 1-1/2-0	6.42 1-0	8.02 X	6.21 4-1/2-0
8	8.09 X	6.53 4-1/2-0	8.12 1-1/2-0	6.42 X	7.89 1-0	5.05 1-1/2-0
9	7.86 1-1/2-0	6.50 1-1/2-0	8.14 1-0	6.32 X	7.67 X	5.92 X
10	99.89 S	4.18 1/2-0	99.89 S	6.32 X	7.57 2-0	5.81 1-0
11	6.17 1-0	4.68 2-0	6.39 X	4.59 4-0	5.96 X	4.28 X

Notes: 1. This device utilized a double electrode design. The "1/2" designation indicates one line of a finger to be affected.

2. The symbol "0" indicates a visual open, "S" indicates a visual short, "X" indicates no flaws in the active area.

It was noted that the capacitance values varied considerably for visually acceptable transducers (4.28 to 8.3 pf for the wafer in Table 5.3-2). This made the detection of excessive opens infeasible using capacitance measurement techniques. The measurement accuracy of C values was felt to be approximately one percent. However, effects [illegible]ng to the probe contact cannot be evaluated. Lead and stray capaci[illegible] were calibrated out in the computer. As can be seen in [illegible], this test approach detected shorts 5/5 times. However, low [illegible] values were recorded and indicated three time failures, [illegible] were visually acceptable. In all likelihood, the probe was [illegible] with the pad on these die. This observation is supported

TABLE 5.3-3. CAPACITANCE PROBE/VISUAL FAILURE SUMMARY

		Visual Reject				Cap Probe Reject	
		Open		Short			
Row	Column	I	O	I	O	I	O
1	2			X		X	X
1	3					X	X
2	2		X				
3	2	X					
4	1				X		X
5	1		X				
5	2	X					
5	3	X			X		X
6	1	X					
7	3		X				
8	1		X				
10	1			X		X	
10	2			X		X	
11	2		X				

Note: 1. X indicates a failure of requisite criteria.
2. Shaded area indicates cap probe failure with no visual flaws

by the fact that the probing station scratched and damaged many of the pads, in some cases removing metal completely down to the crystal surface. These types of problems could be eliminated. A more significant problem relates to the fact that zero of nine visually rejectable opens were detected using the capacitance measuring technique for the wafer in Table 5.3-3. Use of the probing technique to detect shorts would therefore not eliminate a visual inspection for all but the most defect tolerant designs.

5.4.0 CONCLUSIONS FROM PHASE IV

The Pilot Production line was fully implemented in Phase IV, with analyses and presentation of all equipments, facilities, and equipment cost required for the production line. Certain aspects of the production line were processed using an unbalanced approach – notably the package seal, symbolization, environmental testing, and leak testing. All batch processes and tests were defined and developed prior to initiation of pilot production. Pilot production was accomplished with the shipment of the following quantities of devices: 120 BP-Q, 144 BP-LN, 150 PC-Q, 146 PC-LN, 137 TDL-100, 150 TDL-200. Some devices were shipped short due to a shortage of packages, with a prohibitively long delivery time. Environmental testing was performed at the sampling rates specified with no lot rejections. Yields at each process step in the production were established, as were device material quantity and labor per process step. These data were used to calculate the pilot production device cost. Extrapolations of yields to higher production volumes were performed and cost recalculated.

Substantial losses were noted due to electrical failures between precap electrical test and final electrical test. Additional losses were encountered due to low hermeticity yields for some device types. Low hermeticity yields caused a process change from hand soldering to projection welding, with the limitations of both approaches elucidated. Correlation between visual flaws, electrical performance, and measured transducer capacitance were established. The visual inspection approach is the only one feasible at this time, indicating the importance of establishing clean facilities to minimize the reject rate due to airborne particulates. Differences were noted in the devices prototyped in a different laboratory, demonstrating the need to fabricate prototype devices in the production area.

APPENDIX XI
SAMPLE SHOCK AND VIBRATION TEST REPORT FOR BP-LN AND PC-LN DEVICES

HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

HUGHES

HUGHES AIRCRAFT COMPANY
GROUND SYSTEMS GROUP

ENVIRONMENTAL TEST PROCEEDINGS

ACCOMMODATION TESTS

SAW MMT DEVICES

EL. 8731

JOURNAL NO. A 00380

ENVIRONMENTAL TEST PROCEEDINGS JOURNAL

Test Start Date: 11-4-76 Test Complete Date: ________ WA# 8731

Test Type

- [ ] Lt. Wt. Shock
- [ ] Vibration
- [ ] Inclination
- [ ] Md. Wt. Shock
- [ ] Bounce
- [ ] Road
- [ ] Other

Test Eng. D. BROWN C.A. # 1324-204-306217

GSI [ ] Yes [X] No P.R. # 662478

Test Requestor: KEN BLOSSOM Ext. 2614 Org. Code 19-66-26

Customer: ________ ~~P.O.~~ # ________

Address: ________ Part Number PC-LN - 24 PCS. BP-LN - 24 PCS.

Part Name SAW MMT DEVICES

Test Witnesses:

Monitored by:

Test Engineer ________ QA ________

Test Technician Ed Vandiest AFQAR ________

HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

Test Procedure: **Date:** 11-4-76

List or attach pertinent specifications:

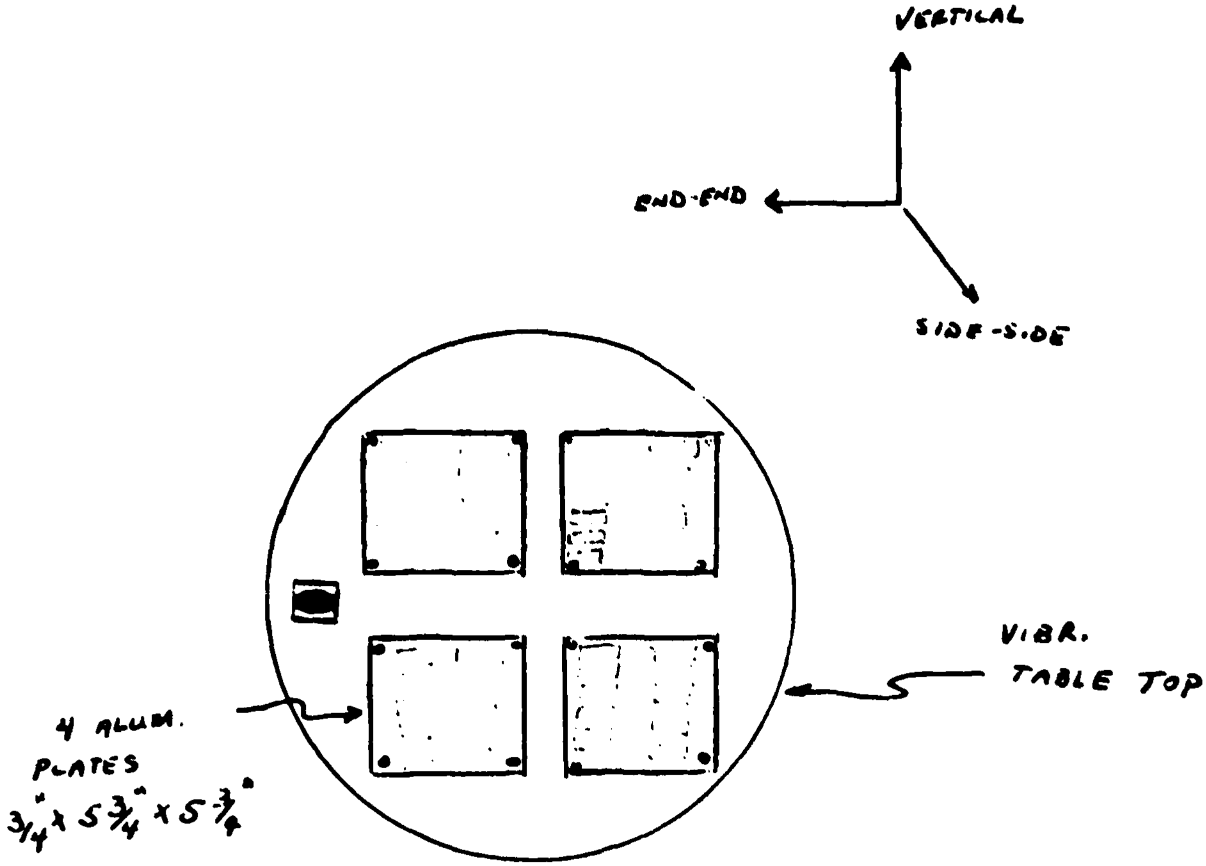
Perform shock and vibration test on 48
SAW MMT I.C. Devices per.

1. mil-Std. 202 method 213 test condition I
   100 G PK sawtooth 6 m sec. ± 3
   shocks 3 axis, total 18

2. Vibration per mil-Std 202 method 201
   5-55 HZ @ .060 DA.
   5-55-5 HZ @ .060 DA cycle time approx.
   1 min. cycle. for 2 hours each axis
   (3 axis) total 6 hrs.

Data Recorder Ted Vondinal
Page 2

Test Procedure Cont'd: Date: 11-4-76



Data Recorder: ______________
Page 3

HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

Test Data: **Date:** 11-4-76

Record all data and observations as test is conducted.

P/N BP-LN

S/N	26	63	46
	13	28	73
	34	48	71
	76	75	80
	57	56	38
	77	11	79
	44	42	
	70	44	
	45	43	

P/N PC-LN

S/N	30	2	14
	31	3	45
	49	36	64
	22	28	46
	23	58	13
	9	34	66
	26	32	
	48	20	
	88	61	

NOTE! (2) pins were broken during installation to connectors prior to Unit testing. 1 pin on S/N 36 & 1 pin on S/N 75
[illegible]

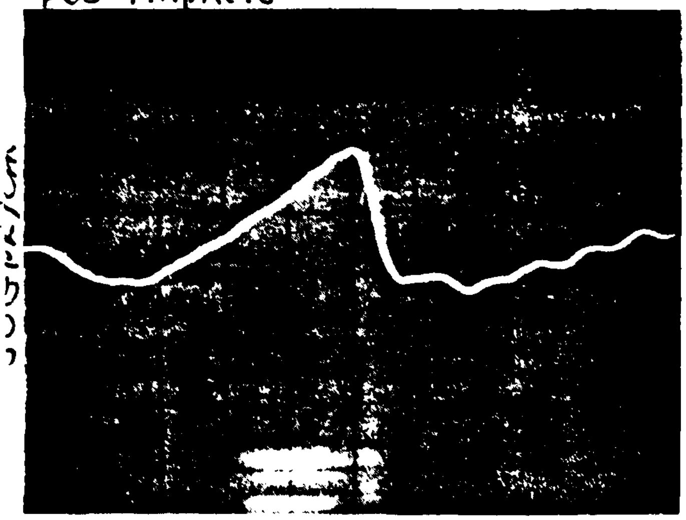
Data Recorder [illegible]
Page 4

Test Data Cont'd: Date: 10-9-76

SHOCK TEST PER MIL STD 202 METHOD 213
TEST COND I 6msec 100 G PK SAWTOOTH.

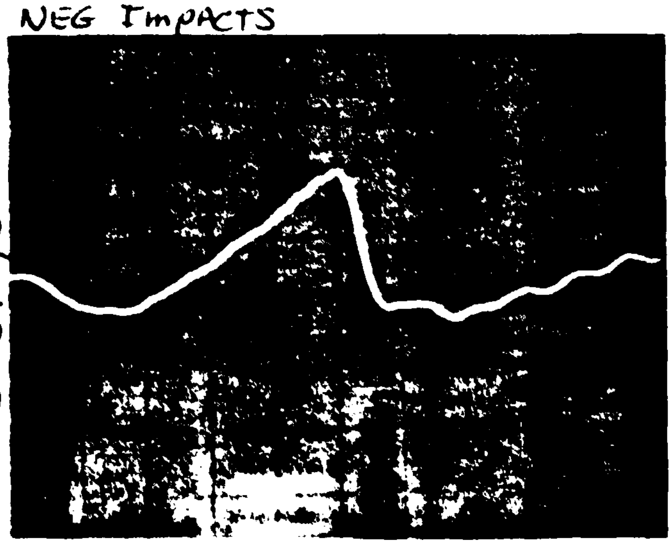
BP-LN P/N's LISTED ON PAGE 4 AND P/N PC-LN S/N' LISTED ON PAGE 4 WERE SUBJECTED TO ± 3 SHOCKS PER AXIS (3 AXIS TOTAL 18). NO APPARENT MECHANICAL DAMAGE NOTED.

POS IMPACTS



2 msec/cm

NEG IMPACTS



2 msec/cm

Test Data Cont'd: Date: 11-4-76

ELAPSED TIME	
2372.7	STARTED SIDE-SIDE AXIS.
2374.7	COMPLETED SIDE-SIDE AXIS (2) HRS
2374.7	STARTED FRONT TO BACK AXIS
2376.7	COMPLETED FRONT TO BACK AXIS (2) HRS
2376.7	STARTED VERTICAL AXIS
2378.7	COMPLETED VERTICAL AXIS (2) HRS

11-19-76
Rec'd. 48 SAW MMT Devices. (2nd Set of Devices)
24 ea. BP-LN
24 ea PC-LN
Devices were mounted in individual sockets therefore S/N identification was not performed. Due to 2 pins being broken on the previous series. It was requested that the devices be mounted prior to shipping to Envir. Eng for test.

11-22-76 Vibration test per MilStd 202 Meth 201 5-55-5 HZ @ .06" DA in the three (3) mutually perpendicular axis was performed. No apparent damage resulted due to vibration.

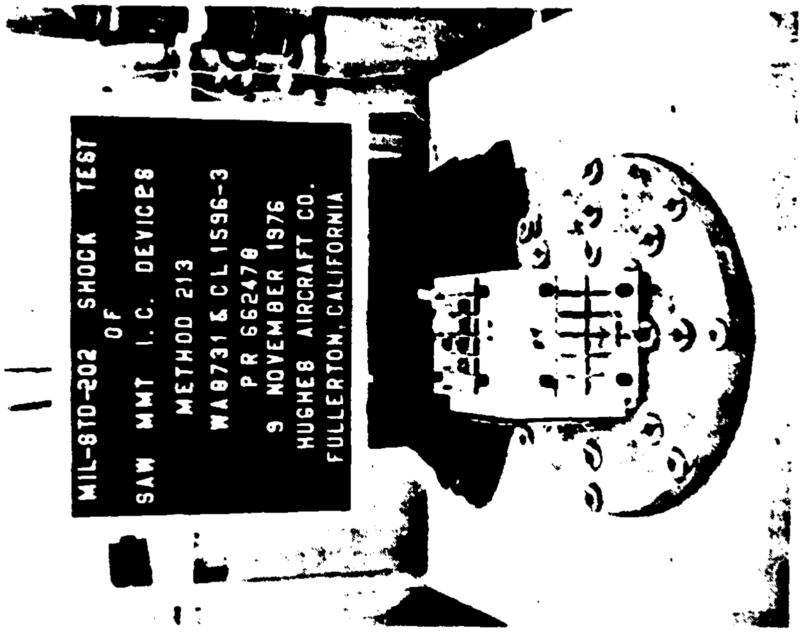
11-23-76 Test specimens returned for electrical performance test. No photographs of the test setups were made due to duplication. Refer to GS 76-11-213 Photograph for test configuration.

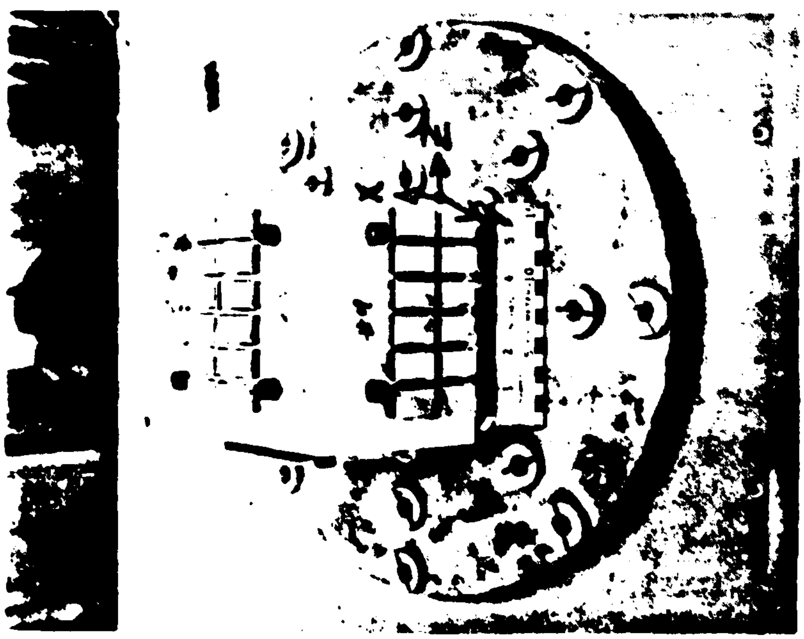
11-23/11-24
48 test specimens returned from electrical performance test.
48 test specimens subjected to shock testing per Mil Std 202 Method 213 Test Cond I 100G 6 Msec Sawtooth

Data Recorder D. Brown
Page 6

Con't page 8

Test Data Cont'd: Date: 10-9-76





SHOCK test set up.

HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

Test Data Cont'd: Date: 11-23-76

Each test specimen subjected to ± 3 shock in each of 3 mutually perpendicular axis.
Upon completion of testing units were visually inspected. No damage observed. No photograph was performed and photos of input pulse were not performed however pulse on page 7 is representative of pulse shape and amplitude during this test.
Test specimens returned for electrical testing.
WJB

Received & mounted 24 SAW MMT Devices 12-21-76
P/N TDL-200 (12 TDL-100 AND 12 TDL-200)
Mounted devices on 5¾" square plate using double-faced tape
4 devices/plate on six (6) plates.
Vibration to be perform per Mil-Std. 202 Method 201
Sweep 5-55-5HZ @ .06" D.A. in one (1) Min. for 2 HRS./Each of three (3) Axes, mutually perpendicular.

15:33 Start Vibration. Cycling as noted above for 2 Hrs. along Vert. Axis.

12-22-76

18:50 Completed Vert. axis. No apparent visual mechanical damage noted.

19:05 Start of side to side axis, Cycling as above for 2 Hrs.

11:05 Completed side to side axis.
No apparent visual mechanical damage noted.

1:16 Start of End to End axis for 2 Hrs. Same sweep & amplitude as above.

3:10 2 Hrs. Cycling completed. No apparent visual indication of mechanical damage noted.
Units to be returned for Electrical testing.

Data Recorder B. Nick

Page 8

Test Equipment — Date: 11-4-76

	Item	Cal Due Date
☐	Shock Machine, LW High-Impact, BuShips 10-T-2145-L	
☐	Shock Machine, MW High-Impact, BuShips 807-655947	
☐	Vibration Table, Low Frequency, LAB RVH 72-5000	
☐	Vibration Table, Low Frequency, LAB RVH 72-2500	
☐	Vibration Table, Low Frequency, LAB RVH 48-1000	
☒	Vibration Table, Low Frequency, LAB RVH ~~36-500~~ 24-40	apr 1, 77
☐	Inclination Test Machine, Hughes	
☐	Package Tester, LAB Type 1000 SC	
☐	Boost Pump, Sprague, Model 216-C-150	
☐	Boost Pump, Sprague, Model S-4406S-35	
☐	Gauge, Heise, 0-70 PSI, S/N 24927	
☐	Gauge, Heise, 0-70 PSI, S/N 24929	
☐	Gauge, Heise, 0-100 PSI, S/N 24932	
☐	Gauge, Heise, 0-500 PSI, S/N 24939	
☐	Gauge, Heise, 0-500 PSI, S/N 24244	
☐	Gauge, Marsh, 0-300 PSI, Type 220-4S	
☐	Gauge, Marsh, 0-1000 PSI, Type 220-4S	
☐	Gauge, Marsh, 0-1500 PSI, Type 220-4S	
☐	Gauge, Marsh, 0-3000 PSI, Type 220-4S	
☐	Gauge, Marsh, 0-5000 PSI, Type 220-4S	
☐	Gauge, Marsh, 0-10,000 PSI, Type 220-4S	
☐	Gauge, Sprague, 0-20,000 PSI	
☒	Vibration Meter, Bell & Howell Type 1-157 H-307252 H-321866	Feb 9, 77 3-9-77
☐	Vibration Meter, CEC Type 1-117	
☒	Vibration Pick Up, CEC Type 4-102A S/N 13844	Oct 24, 77
☒	Universal Timer, Dimco Gray Model 167	April 4, 78
☐	Vehicular Adaptor Plate, LAB 2-1/4" x 36" x 36"	
☐	Universal Eput Meter, Beckman Model 7360-43	
☐	Strobex, Bruel and Kjorr, Type 4910	
☐	Strobex, Bruel and Kjorr, Type 4911	
☐	Other	
☐	Other	
☐	Other	

Data Recorder: Ed Vanlinst

Page 13

AD-A081 126 HUGHES AIRCRAFT CO FULLERTON CA GROUND SYSTEMS GROUP F/G 9/5
PHOTOLITHOGRAPHIC TECHNIQUES FOR SURFACE ACOUSTIC WAVE (SAW) DE--ETC(U)
DEC 78 A W DOZIER DAAB07-75-C-0044
UNCLASSIFIED HAC-FR-79-12-40-VOL-4 DELET-TR-75-0044-F-V-4 NL

2 OF 3
AD
A081126

SHOCK TEST

EQUIPMENT	MANUFACTURER	MODEL	GOVT. OR HAC I.D. NO.	SERIAL NO.	CAL DUE DATE
accelerometer	Endevco corp.	2272	E066	AU30	5-9-77
charge amp.	Unholtz-Dickie	D-11	H-916102		5-2-78
Krohn-Hite Filter	Krohn-Hite	3322R	H-198585		10-20-77
waveform Synthesizer	Exact	201	H-305673		
Strain Scope	Hewlett Packard. Mainframe Time Base Dual Amp	1418 1421A 1402A	H-307288 H-307289 H-307290		11-18-76 11-18-76 11-18-76
oscillator	Spectral Dynamics	SD104A-5	H-300527		2-16-77
Power amp.	Unholtz-Dickie	TA104	H-300574		Calib As Req'd
Shaker.	Unholtz-Dickie	1003M	H-300515		Calib As Req'd
VIBRATION METER	BELL + HOWELL	1-157	H-321066	-	3-9-77
VIBRATION MACHINE	LAB	24-100	H-29009	-	4-1-77
TIMER	DIMCO GRAY	167	H-303363	-	4-4-78

APPENDIX XII
QUALITY ASSURANCE QUALITY METHOD SHEET MICROELECTRONICS

1.0 PURPOSE

To provide instructions for the visual inspection of Surface Acoustic Wave (SAW) devices manufactured on metallized crystalline substrate material by a deposition, photolithographic exposure, and chemical etch process.

2.0 SCOPE

This instruction covers the visual inspection requirements for all SAW devices made by the deposition of a metallized conductor on a crystalline substrate and then using either a selective etch or liftoff process to remove all but the desired pattern.

3.0 INSPECTION

3.1 Materials - All materials utilized in the processing of crystal circuits are described in Process Engineering Instruction (PEI) 7.18.00, Acoustic Wave Processing.

3.2 Equipment - All equipment required for the fabrication of SAW devices is described within the appropriate sections of PEI 7.18.00, Acoustic Wave Processing.

3.3 Procedure - Unless otherwise specified, the process sequence shall be performed as outlined on SAW process followers, and processed according to the appropriate PEIs referenced thereon.

3.3.1 Handling - Crystals shall remain in protective containers until process and inspection operations are to be performed. Finger cots or other hand protection shall be worn at all times to prevent damage and contamination. Devices shall be handled only on the sides and never by the metallized surface. Device packages (headers) shall be handled by non-sealing surfaces only.

3.3.2 Crystal Cutting and Sorting - Wafers shall be separated into individual circuit crystals before visual inspection. After separating, crystals shall be cleaned in a manner sufficient to remove all foreign material. Crystals shall be sorted into lots and properly identified by the use of a standard process follower.

3.3.3 Adhesion - Crystals shall exhibit uniform adhesion. There shall be no evidence of separation of the metallization from the crystal substrate when tested with adhesive tape. The adhesion test shall be performed for process certification on production circuits. A length of commercial, clear, or translucent plastic tape shall be applied to the metallized, etched substrate. The tape shall cover an area of at least 1/2 inch and shall be set by rubbing with a finger. The tape shall be pulled back at

an angle of approximately 90° to the crystal using one smooth motion. The metallized layers shall not show any evidence of separation when examined at 30 to 100 power magnification.

3.3.4 Process Control - Described in Quality Method Sheet (QMS) M-001, Microelectronics Process Surveillance.

3.4 Quality Assurance Provisions

3.4.1 Responsibility - The Quality Assurance Group Office (QAGO) shall be the cognizant Quality organization exercising control over all processing heretofore described.

3.4.2 Inspection - Crystals produced shall be inspected to the requirements of the device engineering drawing and workmanship standards contained in Section 3.5 and Table I of this QMS.

3.5 Workmanship

3.5.1 General - Crystals shall be visually examined under 30 power magnification (minimum) for conformance to the workmanship requirements contained herein. Transmitted light shall be used where applicable. Crystals not conforming to the requirements contained herein shall be rejected unless they can be reworked to conform to the specified requirements. Reworked crystals are to be resubmitted for verification of conformance to the electrical and visual requirements specified herein.

3.5.2 End Product Requirements - SAW devices shall conform to the visual requirements of the appropriate engineering drawing, device specification, and workmanship standards contained herein. The following irregularities and those shown in Table I of this QMS shall be cause for rejection.

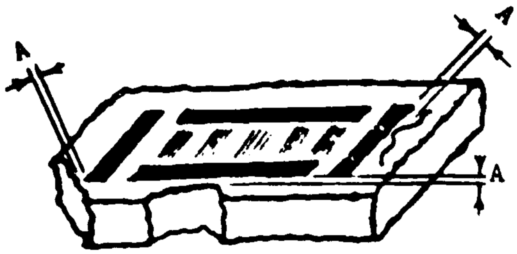
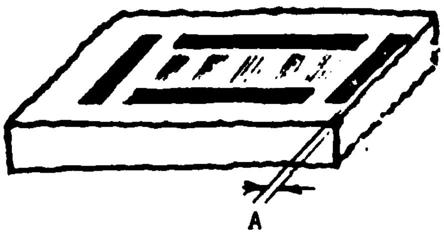
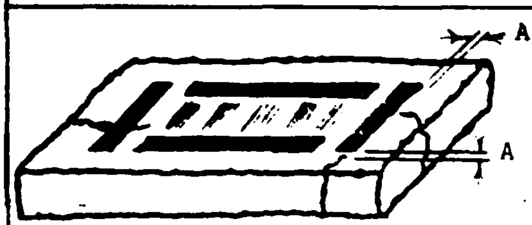
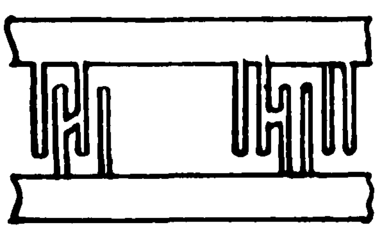
a. Chips or cracks in the crystal material which come closer than 25 microns (1 mil) to any active metallization.
b. Scribing edge of the crystal material that is closer than 25 microns (1 mil) to any metallization.
c. Any crack which extends into or points toward and comes within 127 microns (5 mils) of active metallization.
d. Scratches, voids, or holes which reduce the bonding pad to transducer finger interconnect to less than 50 percent of original design width.
e. Scratches, voids, or holes which reduce bonding pads to less than 50 percent of original design width.
f. Attached opaque contamination which cannot be removed by cleaning procedures and appears to be shorted to adjacent transducer fingers that are not connected to the same pad.

g. Shorts between transducer fingers not connected to the same pad which cannot be blown during device test.
h. Lifting or peeling metallization.

NOTE: Opens, voids, or scratches on transducer fingers which do not affect electrical characteristics are acceptable.

D. J. Davis
Quality Assurance

TABLE I

Illustration	Requirement
	Reject - A is less than 1 mil (25.4 microns or .001 inch) between metallization and chips or cracks in crystal substrate material.
	Reject - Scribing edge of crystal material comes closer than 25 microns (1 mil) to active metallization.
	Reject - Any crack which extends into or points toward and comes within 127 microns (5 mils) of active metallization.
	Reject - Scratches, voids, or holes which reduces any bonding pad or transducer interconnect to less than 50 percent of original design width.
	Reject - Shorts between transducer fingers that are not connected to the same interconnect pad which cannot be removed during test.

APPENDIX XIII

PHASE III ELECTRICAL DATA

BP-Q FINAL DATA PHASE III

S/N	Center Freq. f_o (MHz) 100 ±2	Bandwidth B (MHz) 2 ±0.04	Insertion Loss L_{ins} (dB) 20 ±2	Sidelobes Lead/Trail S_{sl} (dB) ≥ 35	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out ≤ 2:1	Examination or Test Group
1	100.23	2.03	20	50/50	56	41	<<	I, V, VI
2	100.23	2.02	18	50/50	60	38	<<	I, V, VI
3	100.21	1.97	20	50/50	51	39	<<	I, III, IV, V
4	100.20	1.99	19.5	50/50	60	41	<<	I, V, VI
5	100.012	2.02	19.0	50/40	51	39	<<	I, V, VI
6	100.05	1.99	18.0	47/55	50	37	<<	I, V, VI
7	100.20	1.96	19	40/40	60	40	<<	I, V
*8			>>20				>	I, V, VI
10	100.20	1.98	18	50/50	60	39	<<	I, III, IV, V
11	100.22	1.99	18	50/50	60	39	<<	I, V, VI
12	100.21	1.96	19	50/50	60	36	<<	I, V, VI
13	100.19	1.99	19	50/50	60	40	<<	I, V, VI
14	100.20	1.98	18	40/40	60	40	<<	I, III, IV, V
15	100.22	2.01	18	40/40	60	39	<<	I, III, IV, V
16	100.19	1.97	19	50/50	60	40	<<	I, V, VI
18	100.20	1.97	20	40/40	50	50	<<	I, III, IV, V
20	100.19	1.99	19.5	40/40	60	41	<<	I, V, VI
21	100.17	2.01	20	50/50	60	40	<<	I, III, IV, V
22	100.20	1.97	20	50/50	56	40	<<	I, III, IV, V
23	100.21	1.98	19	50/50	53	39	<<	I, V, VI
24	100.00	2.01	20	50/50	55	41	<<	I, V, VI
28	100.21	2.00	19	50/50	50	39	<<	I, V, VI
29	100.21	1.98	19	50/50	60	39	<<	I, III, IV, V

*Failed electrical test.

BP-Q FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 100 ±2	Bandwidth B (MHz) 2 ±0.04	Insertion Loss Lins (dB) 20 ±2	Sidelobes Lead/Trail S_{sl} (dB) ≥ 35	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out $\leq 2:1$	Examination or Test Group
30	100.21	1.98	19.5	45/45	52	40	<<	I, III, IV, V
31	100.157	1.99	19.5	50/50	53	40	<<	I, V, VI
32	100.20	1.99	18.0	42/40	59	38	<<	I, V, VI
33	100.20	1.96	19.5	40/40	60	41	<<	I, III, IV, V
34	100.23	1.96	18.5	35/40	50	38	<<	I, V, VI
35	99.98	1.98	19.5	50/50	62	38	<<	I, V, VI
36	100.23	1.96	19.5	50/40	60	40	<<	I, III, IV, V
37	100.22	1.96	19	50/50	75	39	<<	I, III, IV, V
38	100.21	1.96	19	40/40	60	38	<<	I, III, IV, V
39	100.20	1.96	19	40/40	60	40	<<	I, V, VI
40	100.22	2.00	19.5	40/40	60	38	<<	I, V, VI
41	100.17	2.00	19	40/40	55	41	<<	I, III, IV, V
42	100.21	1.98	19.5	40/40	60	41	<<	I, V, VI
43	100.18	1.96	19.0	50/50	55	41	<<	I, V, VI
44	100.21	1.96	20	50/50	60	39	<<	I, III, IV, V
45	100.21	1.96	20	50/50	60	39	<<	I, III, IV, V
46	100.19	1.96	19.5	40/40	54	40	<<	I, V
47	100.22	1.97	19	50/50	60	41	<<	I, V, VI
49	100.20	2.02	29.5	50/50	60	39	<<	I, III, IV, V
50	100.24	2.00	20	50/50	60	42	<<	I, III, IV, V
53	100.28	1.98	19	45/40	60	39	<<	I, V, VI
67	100.19	1.98	18	40/40	60	39	<<	I, V
68	100.19	1.99	18	40/40	53	40	<<	I, V

BP-Q FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 100 ±2	Bandwidth B (MHz) 2 ±0.04	Insertion Loss L_{ins} (dB) 20 ±2	Sidelobes Lead/Trail S_{sl} (dB) ≥ 35	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out ≤ 2.1	Examination or Test Group
69	100.19	1.97	18	40/40	60	40	<<	I, V
70	100.19	1.97	18	40/40	60	40	<<	I, V
71	100.19	1.99	18.5	40/40	55	40	<<	I, V
72	100.20	1.98	18.5	40/40	60	40	<<	I, V

Note: VSWR measurements were made using return loss measurements.
Actual VSWR was not recorded/calculated to save test time.

BPLN FINAL DATA PHASE III

S/N	Center Freq. f_o (MHz) 150 ±3	Bandwidth B (MHz) 30 ±0.6	Insertion Loss L_{ins} (dB) 20 ±1.5	Sidelobes Lead/Trail S_{sl} (dB) ≤ 35	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out ≤ 3:1	Examination or Test Group
1	151.00	29.6	18.5	37/45	50	35	<<	I, III, IV, V
2	151.10	29.4	19.5	35/45	60	36	<<	I, III, IV, V
4	151.10	29.8	18.5	35/40	50	35	<<	I, III, IV, V
7	150.95	29.5	19	40/45	60	36	<<	I, III, IV, V
8	151.20	30.6	20	36/45	50	37	<<	I, III, IV, V
10	150.75	29.5	18.5	35/40	50	35	<<	I, III, IV, V
12	150.65	29.7	18.5	35/40	50	38	<<	I, III, IV, V
14	150.95	29.7	18.5	37/40	60	36	<<	I, III, IV, V
15	151.25	29.7	20	27/45	60	38	<<	I, III, IV, V
17	150.60	29.4	19.5	37/40	50	39	<<	I, III, IV, V
18	150.80	29.8	18.5	35/37	60	36	<<	I, III, IV, V
19	150.95	30.3	18.5	35/40	50	36	<<	I, III, IV, V
20	150.70	29.8	18.5	35/45	60	35	<<	I, III, IV, V
21	150.55	29.5	18.5	35/40	60	35	<<	I, III, IV, V
22	151.05	30.5	18.5	35/40	60	36	<<	I, III, IV, V
23	150.70	29.8	18.5	35/40	60	35	<<	I, V
24	150.70	30.0	18.5	35/40	60	35	<<	I, III, IV, V
27	150.80	30.0	18.5	35/40	60	35	<<	I, V
29	150.70	29.8	18.5	40/45	50	35	<<	I, III, IV, V
31	150.90	30.2	18.5	37/40	60	35	<<	I, V
32	150.95	30.1	20	35/45	60	36	<<	I, V
35	150.90	29.5	18	35/45	60	35	<<	I, V, VI
36	150.75	30.1	18.5	35/40	60	35	<<	I, V

BPLN FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 150 ±3	Bandwidth B (MHz) 30 ±0.6	Insertion Loss L_{ins} (dB) 20 ±1.5	Sidelobes Lead/Trail S_{sl} (dB) ≥ 35	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out ≤ 3:1	Examination or Test Group
37	151.20	29.8	29	35/40	50	37	✓✓	I, III, IV, V
39	151.35	29.9	18.5	35/40	60	35	✓✓	I, V
40	150.80	29.6	19	37/40	60	35	✓✓	I, V, VI
45	151.40	30.2	18.5	37/40	60	35	✓✓	I, V, VI
53	151.15	29.9	18.5	40/40	60	36	✓✓	I, V
56	151.15	29.9	19.5	40/45	60	36	✓✓	I, V
57	151.05	29.5	18.5	35/40	60	35	✓✓	I, V, VI
58	150.95	29.7	19	40/40	60	36	✓✓	I, V, VI
*75								
11	151.00	30.2	19	40/45	60	36	✓✓	I, V, VI
13	151.00	30.2	18.5	35/40	60	35	✓✓	I, V, VI
26	150.75	29.7	18.5	37/40	60	36	✓✓	I, V, VI
28	150.85	29.7	18.5	35/45	60	35	✓✓	I, V, VI
34	151.10	29.8	20	37/45	60	39	✓✓	I, V, VI
38	150.95	29.7	20	36/45	60	38	✓✓	I, V, VI
42	150.75	29.5	18.5	37/45	60	37	✓✓	I, V, VI
43	150.80	29.6	19	38/45	60	36	✓✓	I, V, VI
44	151.10	29.4	19	35/45	55	37	✓✓	I, V, VI
46	150.90	29.6	18.5	36/45	60	37	✓✓	I, V, VI
48	151.10	29.4	19	40/45	60	38	✓✓	I, V, VI
63	150.90	29.8	20.5	40/45	60	41	✓✓	I, V, VI

*Broken Pin

BPLN FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 150 ±3	Bandwidth B (MHz) 30 ±0.6	Insertion Loss L_{ins} (dB) 20 ±1.5	Sidelobes Lead/Trail S_{sl} (dB) ≥ 35	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out $\leq 3:1$	Examination or Test Group
70	150.80	29.6	18.5	38/45	60	37	<<	I, V, VI
71	150.75	29.7	18.5	35/45	54	36	<<	I, V, VI
73	150.80	29.4	19.5	40/45	60	38	<<	I, V, VI
76	150.90	29.8	21	40/45	60	37	<<	
77	150.80	29.4	20.5	40/45	60	38	<<	I, V, VI
79	150.80	29.6	20	40/45	60	39	<<	I, V, VI

Note: VSWR measurements were made using Return Loss Measurements.
Actual VSWR was not Recorded/Calculated to save test time.

PCQ FINAL DATA PHASE III

S/N	Insertion Loss L_{ins} (dB) 50 ±5	Sidelobe S_{sl} (dB) $\geq$ 25	Feedthrough S_{ft} (dB) $\geq$ 50	Spurious S_{sp} (dB) $\geq$ 35	In/Out $\leq$2.5:1	Examination or Test Group
1	45.5	31	50	47	<<	I, V, VI
2	46	28	50	37	<<	I, III, IV, V
5	46	33	50	37	<<	I, III, IV, V
7	47.0	28	50	41	<<	I, III, IV, V
* 12			No Data - open			
16	46.5	33	50	41	<<	I, III, IV, V
17	47	33	50	40	<<	I, V, VI
18	49	27	53	40	<<	I, V, VI
19	46	30	50	43	<<	I, III, IV, V
22	45	30	50	37	<<	I, V, VI
23	45	28	50	40	<<	I, III, IV, V
24	46	28	50	42	<<	I, III, IV, V
25	46	28	50	36	<<	I, V, VI
28	46	29	50	36	<<	I, V, VI
29	46.5	29	50	45	<<	I, V, VI
30	52	31	50	38	<<	I, III, IV, V
31	45.5	30	50	42	<<	I, III, IV, V
32	45	29	50	37	<<	I, V, VI
33	46	29	50	43	<<	I, III, IV, V
35	45	29	50	42	<<	I, III, IV, V
36	45	31	50	45	<<	I, V, VI
39	48.5	30	50	37	<<	I, III, IV.V

PCQ FINAL DATA PHASE III (Continued)

S/N	Insertion Loss L_{ins} (dB) 50 ±5	Sidelobe S_{sl} (dB) ≥ 25	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	In/Out ≤ 2.5:1	Examination or Test Group
40	50	30	50	42	<<	I, V, VI
41	47.5	30	50	43	<<	I, III, IV, V
43	46.5	30	50	42	<<	I, III, IV, V
44	45	28	50	38	<<	I, V
45	47	28	50	37	<<	I, III, IV, V
47	49	29	50	40	<<	I, V
48	45.5	29	50	38	<<	I, III, IV, V
49	47	31	50	45	<<	I, V, VI
51	48	30	50	40	<<	I, V
52	45	29	50	35	<<	I, V
* 54	49	17	50	35	<<	I, V, VI
55	48	31	50	45	<<	I, V, VI
58	47.5	31	50	45	<<	I, V, VI
59	45.5	30	50	44	<<	I, V, VI
61	47	30	50	36	<<	I, V, VI
62	47	32	50	40	<<	I, III, IV, V
66	46	30	50	45	<<	I, V, VI
* 67	48	20	50	45	<<	I, V, VI
68	47	29	50	36	<<	I, V
69	49	27	50	43	<<	I, V, VI
70	51	31	50	40	<<	I, V, VI
71	48	29	50	35	<<	I, V
72	47	29	50	35	<<	I, V

PCQ FINAL DATA PHASE III (Continued)

S/N	Insertion Loss L_{ins} (dB) 50 ±5	Sidelobe S_{sl} (dB) ≥ 25	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	In/Out $\leq 2.5:1$	Examination or Test Group
73	46	31	50	46	<<	I, V, VI
74	47.5	30	50	45	<<	I, V, VI
77	48	32	50	35	<<	I, V
81	47	31	50	47	<<	I, V, VI
82	47.5	25	50	46	<<	I, V, VI

*Failed electrical test

Note: VSWR measurements were made using Return Loss Measurements. Actual VSWR was not Recorded/Calculated to save test time.

PCLN FINAL DATA PHASE III

S/N	Insertion Loss L_{ins} (dB) 30 ± 3	Sidelobes Lead/Trail S_{sl} (dB) ≥ 20/25	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out ≤ 3:5:1	Examination or Test Group
1	33	20/25	50	39	<<	I, III, IV, V
2	31	22/25	60	37	<<	I, V, VI
3	32	22/25	60	40	<<	I, V, VI
5	32.5	25/30	50	42	<<	I, III, IV, V
6	32	21/27	50	36	<<	I, III, IV, V
8	32	30/30	52	38	<<	I, V
9	33	21/25	60	37	<<	I, V, VI
10	31	20/25	50	36	<<	I, III, IV, V
11	31.5	20/25	50	38	<<	I, III, IV, V
12	30.5	20/25	50	35	<<	I, III, IV, V
13	32	26/26	60	40	<<	I, V, VI
14	32	24/25	70	38	<<	I, V, VI
15	31	32/32	52	36	<<	I, V
16	32	32/32	50	35	<<	I, V
18	33	21/25	50	35	<<	I, III, IV, V
* 20	33	27/27	60	[illegible]	<<	I, V, VI
21	32	28/28	51	35	<<	I, V
22	33	20/25	60	35	<<	I, V, VI
23	33	31/31	50	42	<<	I, V, VI
25	32	32/32	52	42	<<	I, V
26	33	21/25	60	35	<<	I, V, VI
27	33	32/32	52	38	<<	I, V
28	32.5	20/26	60	35	<<	I, V, VI

PCLN FINAL DATA PHASE III (Continued)

S/N	Insertion Loss L_{ins} (dB) 30 ±3	Sidelobes Lead/Trail S_{sl} (dB) $\geq$ 20/25	Feedthrough S_{ft} (dB) $\geq$ 50	Spurious S_{sp} (dB) $\geq$ 35	VSWR In/Out $\leq$ 3:5:1	Examinations or Test Group
29	33	20/25	50	35	<<	I, III, IV, V
30	32	24/24	60	40	<<	I, V, VI
31	32.5	21/25	60	37	<<	I, V, VI
32	33	22/25	70	36	<<	I, V, VI
33	33	32/32	50	39	<<	I, V
34	31	23/35	60	37	<<	I, V, VI
35	33	27/27	60	41	<<	I, V
**36	32	22/25	70	36	<<	I, V, VI
38	32	22/26	60	38	<<	I, V, VI
40	32	20/25	50	39	<<	I, III, IV, V
41	32	22/25	60	37	<<	I, III, IV, V
43	31.5	20/25	50	36	<<	I, III, IV, V
45	32	21/25	70	37	<<	I, V, VI
46	33	25/25	60	35	<<	I, V, VI
47	31.5	20/25	50	35	<<	I, III, IV, V
48	32	22/25	60	37	<<	I, V, VI
49	32	24/27	61	41	<<	I, V, VI
*51	31.5	23/25	50	32	<<	I, III, IV, V
52	32	21/25	50	35	<<	I, III, IV, V
56	32	20/25	50	36	<<	I, III, IV, V
58	32	21/25	60	36	<<	I, V, VI
59	33	20/25	50	35	<<	I, III, IV, V
61	32	21/25	60	35	<<	I, V, VI

PCLN FINAL DATA PHASE III (Continued)

S/N	Insertion Loss L_{ins} (dB) 30 ±3	Lead/Trail S_{sl} (dB) ≥20/25	Feedthrough S_{ft} (dB) ≥50	Spurious S_{sp} (dB) ≥35	VSWR In/Out ≤3:5:1	Examinations or Test Group
64	32	23/25	60	38		I, V, VI
66	32	30/30	51	37		I, V, VI
67	32.5	27/25	50	38		I, III, IV, V
68	32	21/25	50	39		I, III, IV, V

*Failed electrical test
**Broken pin

Note: VSWR measurements were made using Return Loss Measurements. Actual VSWR was not Recorded/Calculated to save test time.

TDL-100 FINAL DATA PHASE III

S/N	Center Freq. f_o (MHz) 100 ±2	Insertion Loss L_{ins} (dB) 27 ±3	Sidelobe S_{sl} (dB) ≥ 17	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out $\leq 4:1$	Examination or Test Group
1	100.116	27	18	50	38	<<	I, V
2	100.073	28	17	52	36	<<	I, V, VI
3	100.069	30	19	55	37	<<	I, V, VI
4	100.114	30	18	50	38	<<	I,V
6	100.132	29	18	50	38	<<	I, V
8	100.121	28	17	50	36		I, V
9	100.117	27	18	50	37	<<	I, V
*10	100.082	28	15	55	37	<<	I, V, VI
12	100.116	28	18	50	36	<<	I, V
16	100.117	27	19	50	35	<<	I, V
17	100.117	27	19	50	36	<<	I, V
19	100.086	28	19	55	38	<<	I, V, VI
20	100.082	28	19	55	37	<<	I, V, VI
21	100.078	27	19	55	36	<<	I, V, VI
22	100.111	27	18	50	36	<<	I, V
23	100.076	26	20	55	36	<<	I, V
24	100.064	27	19	55	36	<<	I, V
25	100.086	29	19	55	37	<<	I, V, VI
27	100.123	28	18	50	37	<<	I, V
28	100.078	27	19	55	36	<<	I, V
30	100.121	30	19	50	39	<<	I, V
31	100.069	29	18	55	36	<<	I, V, VI

*Failed Electrical test

TDL-100 FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 100 ±2	Insertion Loss L_{ins} (dB) 27 ±3	Sidelobe S_{sl} (dB) ≥ 17	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out $\leq 4:1$	Examination or Test Group
32	100.075	26	20	55	37	<<	I, V, VI
33	100.067	27	29	55	38	<<	I, V
34	100.086	27	19	55	36		I, V, VI
39	100.118	30	18	50	36	<<	I, V
40	100.119	30	18	50	36	<<	I, V
41	100.088	25	19	55	36	<<	I, V, VI
43	100.083	25	20	55	35	<<	I, V, VI
46	100.079	25	19	55	35	<<	I, V
47	100.072	30	19	55	38	<<	I, V
48	100.126	30	18	50	36	<<	I, V
49	100.079	25	20	55	35	<<	I, V
50	100.077	25	20	55	36	<<	I, V
51	100.086	27	19	55	39	<<	I, V
52	106.074	25	20	55	35	<<	I, V
53	100.082	26	19	55	37	<<	I, V
54	100.07	27	19	50	38	<<	I, V
55	100.084	26	20	50	36	<<	I, V
57	100.087	26	20	50	37	<<	I, III, IV, V
58	100.06	27	19	50	39	<<	I, V
59	100.088	26	19	50	37	<<	I, III, IV, V
*60		-60					I, III, IV, V
61	100.076	26	20	50	37	<<	I, III, IV, V

*Failed electrical test

TDL-100 FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 100±2	Insertion Loss L_{ins} (dB) 27 ±3	Sidelobe S_{sl} (dB) $\geq$17	Feedthrough S_{ft} (dB) $\geq$50	Spurious S_{sp} (dB) $\geq$35	VSWR In/Out $\leq$4:1	Examination or Test Group
62	100.064	26	19	55	37	<<	I, V
67	100.083	26	20	50	36	<<	I, III, IV, V
68	100.081	26	19	50	37	<<	I, III, IV, V
76	100.092	27	20	50	36	<<	I, III, IV, V
78	100.078	27	19	50	37	<<	I, III, IV, V
81	100.087	29	17	50	38	<<	I, III, IV, V

*Failed electrical test

Note: *VSWR measurements were made using Return Loss Measurements.*
Actual VSWR was not Recorded/Calculated to save test time.

TDL-200 FINAL DATA PHASE III

S/N	Center Freq. f_o (MHz) 200 ±2	Insertion Loss L_{ins} (dB) 26 ±3	Sidelobe S_{sl} (dB) ≥ 17	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out $\leq 3:1$	Examination or Test Group
5	200.157	25	19	52	40	<<	I, V
6	200.120	28	19	50	38	<<	I, V, VI
8	200.128	25	18	50	39	<<	I, V
16	200.107	24	18	50	36	<<	I, V, VI
19	200.105	24	18	50	36	<<	I, V, VI
20	200.115	25	17	50	36	<<	I, V
21	200.142	26	19	50	38	<<	I, V, VI
23	200.150	24	18	50	40	<<	I, V
24	200.095	26	18	50	37	<<	I, V, VI
26	200.146	26	18	50	40	<<	I, V, VI
28	200.121	24	19	50	35	<<	I, V, VI
29	200.105	24	17	50	36	<<	I, V, VI
30	200.124	23	20	50	37	<<	I, V, VI
32	200.118	23	20	40	35	<<	I, V, VI
35	200.115	25	18	50	36	<<	I, V
53	200.135	25	20	50	38	<<	I, V, VI
55	200.134	25	19	50	39	<<	I, V
*55B	200.138	25	19	50	39	>>	I, V, VI
59	200.141	27	18	50	42	<<	I, V, VI
60	200.108	27	20	50	39	<<	I, V, VI
62	200.143	27	20	50	37	<<	I, V, VI
64	200.124	27	20	50	40	<<	I, V, VI

*Failed electrical test

TDL-200 FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 200 ±2	Insertion Loss L_{ins} (dB) 26 ±3	Sidelobe S_{sl} (dB) ≥ 17	Feedthrough S_{ft} (dB) ≥ 50	Spurious S_{sp} (dB) ≥ 35	VSWR In/Out $<3:1$	Examination or Test Group
68	200.147	27	20	50	37	<<	I, V, VI
69	200.154	26	17	50	36	<<	I, V, VI
72	200.108	27	20	50	40	<<	I, V, VI
75	200.111	23	20	50	37	<<	I, V, VI
76	200.127	23	21	50	40	<<	I, V, VI
77	200.134	25	20	50	40	<<	I, V, VI
78	200.130	27	18	50	38	<<	I, V, VI
79	200.129	24	20	50	37	<<	I, III, IV, V
80	200.140	24	20	50	36	<<	I, III, IV, V
81	200.129	24	20	50	37	<<	I, III, IV, V
82	200.126	23	20	50	38	<<	I, III, IV, V
84	200.128	23	20	50	39	<<	I, V
86	200.135	23	20	50	40	<<	I, V
87	200.138	24	20	50	37	<<	I, III, IV, V
88	200.141	23	20	50	37	<<	I, III, IV, V
89	200.146	26	20	50	39	<<	I, III, IV, V
91	200.143	23	21	50	37	<<	I, III, IV, V
92A	200.152	23	20	50	37	<<	I, V
*94	200.125	27	17	40	37	>>	I, III, IV, V
97	200.158	23	20	50	37	<<	I, V
97B	200.157	24	20	50	36	<<	I, V
98	200.116	23	20	50	37	<<	I, V

*Failed electrical test

TDL-200 FINAL DATA PHASE III (Continued)

S/N	Center Freq. f_o (MHz) 200 ±2	Insertion Loss L_{ins} (dB) 26 ±3	Sidelobe S_{sl} (dB) ≥17	Feedthrough S_{ft} (dB) ≥50	Spurious S_{sp} (dB0 ≥35	VSWR In/Out ≤3:1	Examination or Test Group
99	200.131	27	20	50	36	<<	I, V
100	200.127	24	20	50	35	<<	I, V
101	200.147	23	20	50	38	<<	I, V
102	200.148	26	19	50	43	<<	I, V
103	200.142	23	20	50	40	<<	I, V
104	200.163	27	17	50	38	<<	I, V
105	200.164	27	17	50	40	<<	I, V

*Failed electrical test

Note: VSWR measurements were made using Return Loss Measurements. Actual VSWR was not Recorded/Calculated to save test time.

Appendix XIV

PHASE IV PRESEAL ELECTRICAL DATA FOR BP-Q DEVICES

BPQ - PRECAP

LDC	SN	98-102 f_o	1.96-2.09 BW	18-22 L_{INS}	35 S_{SL}	50 S_{FT}	35 S_{SP}	2:1 VSWR	f_{lo}	f_{hi}
8-29-77	1	100.18	1.97	18.3	>35	60	40	<<	99.20	101.17
	2	100.18	1.97	18.5	>35	60	41	<<	99.20	101.17
	3	100.18	1.99	18.3	>35	55	41	<<	99.19	101.18
	4	100.17	2.00	18.5	>35	54	41	<<	99.17	101.17
	5	100.17	1.99	18.3	>35	60	41	<<	99.18	101.17
	6	100.19	1.98	19.1	>35	55	42	<<	99.20	101.18
	7	100.17	1.98	18.3	>35	56	41	<<	99.18	101.16
	8	100.19	2.00	18.3	>35	55	41	<<	99.19	101.19
	9	100.18	2.01	18.1	>35	60	40	<<	99.18	101.19
	10	100.14	19.8	18.6	>35	60	40	<<	99.15	101.13
	11	100.19	2.00	18.0	>35	60	38	<<	99.19	101.19
	12	100.18	2.00	18.1	>35	60	40	<<	99.18	101.18
	13	100.18	1.99	18.4	>35	60	40	<<	99.19	101.18
	14	100.17	1.99	18.2	>35	60	40	<<	99.18	101.17
8-30-77	15	100.17	1.98	18.2	>35	60	39	<<	99.18	101.16
	16	100.17	2.01	18.2	>35	60	39	<<	99.17	101.18
	17	100.19	1.98	18.1	>35	60	40	<<	99.20	101.18
	18	100.19	2.01	18.0	>35	60	39	<<	99.19	101.20
	19	100.17	1.98	18.6	>35	60	40	<<	99.18	101.16
	20	100.18	1.99	18.2	>35	60	39	<<	99.19	101.18
	21	100.19	1.98	18.4	>35	60	40	<<	99.20	101.18
	22	100.19	1.98	18.7	>35	60	41	<<	99.20	101.18
	23	100.19	1.98	18.5	>35	60	40	<<	99.20	101.18
	24	100.21	1.98	18.3	>35	60	40	<<	99.22	101.20
	25	100.20	2.00	18.4	>35	60	40	<<	99.20	101.20
	26	100.17	1.99	18.2	>35	60	40	<<	99.18	101.17
	27	100.19	1.98	18.0	>35	60	40	<<	99.20	101.18
	28	100.20	1.98	18.5	>35	60	40	<<	99.21	101.19
	29	100.19	1.98	18.3	>35	60	40	<<	99.20	101.18
	30	100.20	1.98	18.3	>35	60	40	<<	99.21	101.19
	31	100.19	1.98	18.3	>35	60	40	<<	99.20	101.18
8-31-77	32	100.17	1.99	18.5	>35	60	40	<<	99.18	101.17
	33	100.18	1.99	18.4	>35	60	40	<<	99.19	101.18
	34	100.19	1.99	18.3	>35	60	39	<<	99.20	101.19
	35	100.20	1.99	18.9	>35	60	40	<<	99.21	101.20
	36	100.18	1.99	20.8	>35	60	45	<<	99.19	101.18
	37	100.20	2.00	18.6	>35	60	40	<<	99.20	101.20
	38	100.19	1.99	18.4	>35	60	40	<<	99.20	101.19
	39	100.19	1.98	18.5	>35	60	40	<<	99.20	101.18
	40	100.20	2.00	18.6	>35	60	40	<<	99.20	101.20
	41	100.17	1.99	18.1	>35	60	40	<<	99.18	101.17
	42	100.21	1.98	18.3	>35	60	40	<<	99.22	101.20
9-1-77	43	100.19	2.00	18.2	>35	60	40	<<	99.19	101.19
	44	100.18	2.02	18.1	>35	60	40	<<	99.17	101.19
	45	100.18	2.03	18.1	>35	60	40	<<	99.17	101.20
	46	100.19	2.01	18.1	>35	60	40	<<	99.19	101.20
	47	100.20	1.01	18.0	>35	60	40	<<	99.19	101.20

BPQ - PRECAP (Continued)

LDC	SN	98-102 f_o	1.96-2.09 BW	18-22 L_{INS}	35 S_{SL}	50 S_{FT}	35 S_{SP}	2:1 VSWR	f_{lo}	f_{hi}
9-1-77	48	100.18	2.00	18.1	>35	60	40	<<	99.18	101.18
	49	100.19	2.02	18.1	>35	60	40	<<	99.18	101.20
	50	100.18	2.02	18.2	>35	60	40	<<	99.17	101.19
	51	100.19	1.98	18.1	>35	60	40	<<	99.20	101.18
	52	100.20	2.00	18.2	>35	60	40	<<	99.20	101.20
	53	100.17	1.99	18.4	>35	60	40	<<	99.18	101.17
	54	100.19	2.00	18.1	>35	60	40	<<	99.19	101.19
	55	101.18	2.03	18.6	>35	60	43	<<	99.17	101.20
	56	100.21	1.99	18.4	>35	60	40	<<	99.22	101.21
	57	100.19	1.99	18.4	>35	60	40	<<	99.20	101.19
	58	100.19	1.99	18.3	>35	60	40	<<	99.20	101.19
	59	100.19	1.98	18.3	>35	60	40	<<	99.20	101.18
	60	100.16	2.01	18.2	>35	60	40	<<	99.16	101.17
	61	100.19	2.00	18.6	>35	60	40	<<	99.19	101.19
9-6-77	62	100.18	2.00	18.2	>35	60	40	<<	99.18	101.18
	63	100.19	1.98	18.5	>35	60	40	<<	99.20	101.18
	64	100.18	2.00	18.2	>35	60	40	<<	99.18	101.18
	65	100.18	2.02	18.1	>35	60	40	<<	99.17	101.19
	66	100.19	1.98	18.2	>35	60	40	<<	99.20	101.18
	67	100.18	1.99	18.1	>35	60	40	<<	99.19	101.18
	68	100.16	2.01	18.3	>35	60	40	<<	99.16	101.17
	69	100.18	1.99	18.1	>35	60	40	<<	99.19	101.18
	70	100.18	2.00	18.1	>35	60	40	<<	99.18	101.18
	71	100.19	1.99	18.3	>35	60	40	<<	99.20	101.19
	72	100.20	1.98	18.3	>35	60	40	<<	99.21	101.19
	73	100.19	1.98	18.1	>35	60	40	<<	99.20	101.18
	74	100.19	1.98	18.4	>35	60	40	<<	99.20	101.18
	75	100.18	1.99	18.3	>35	60	40	<<	99.19	101.18
	76	100.19	1.99	18.2	>35	60	40	<<	99.20	101.19
	77	100.18	1.99	18.2	>35	60	40	<<	99.19	101.18
	78	100.19	2.00	18.3	>35	60	40	<<	99.19	101.19
	79	100.17	1.98	18.4	>35	60	40	<<	99.18	101.16
	80	100.19	1.98	18.1	>35	60	40	<<	99.20	101.18
	81	100.19	1.98	18.0	>35	60	40	<<	99.20	101.18
9-7-77	82	100.18	2.00	18.4	>35	60	40	<<	99.18	101.18
	83	100.18	2.01	18.1	>35	60	40	<<	99.18	101.19
	84	100.18	1.99	18.4	>35	60	40	<<	99.19	101.18
	85	100.18	1.99	18.4	>35	60	40	<<	99.19	101.18
	86	100.19	1.98	18.4	>35	60	40	<<	99.20	101.18
	87	100.21	1.98	18.3	>35	60	40	<<	99.22	101.20
	88	100.20	2.00	18.8	>35	60	40	<<	99.20	101.20
	89	100.19	2.00	18.1	>35	60	40	<<	99.19	101.20
	90	100.18	2.00	18.4	>35	60	40	<<	99.18	101.18
	91	100.20	1.98	18.5	>35	60	40	<<	99.19	101.21
	92	100.18	1.97	19.2	>35	60	43	<<	99.20	101.17
	93	100.20	2.00	18.5	>35	60	40	<<	99.20	101.20
	94	100.20	1.98	18.5	>35	60	40	<<	99.21	101.19

BPQ - PRECAP (Continued)

LDC	SN	98-102 f_o	1.96-1.04 BW	18-22 L_{INS}	35 S_{SL}	50 S_{FT}	35 S_{SP}	2:1 VSWR	f_{lo}	f_{hi}
9-7-77	95	100.19	2.02	18.3	>35	60	40	<<	99.18	101.20
	96	100.19	2.00	18.3	>35	60	40	<<	99.19	101.19
	97	100.18	1.99	18.4	>35	60	40	<<	99.19	101.18
9-8-77	98	100.19	2.02	18.3	>35	60	40	<<	99.18	101.20
	99	100.19	1.99	18.1	>35	60	40	<<	99.20	101.19
	100	100.20	2.00	18.5	>35	60	40	<<	99.20	101.20
	101	100.17	2.00	18.3	>35	60	40	<<	99.17	101.17
	102	100.19	1.99	18.4	>35	60	40	<<	99.20	101.19
	103	100.17	1.99	18.3	>35	60	40	<<	99.18	101.17
	104	100.16	1.99	18.2	>35	60	40	<<	99.17	101.16
	105	100.19	2.00	18.3	>35	60	40	<<	99.19	101.19
	106	100.20	1.98	18.3	>35	60	40	<<	99.21	101.19
	107	100.18	2.00	18.3	>35	60	40	<<	99.18	101.18
9-13-77	108	100.21	1.97	18.5	>35	60	40	<<	99.12	101.20
	109	100.18	2.00	18.2	>35	60	40	<<	99.18	101.18
	110	100.22	2.00	18.2	>35	60	40	<<	99.22	101.22
	111	100.21	1.98	18.1	>35	60	42	<<	99.22	101.20
	112	100.16	2.00	18.6	>35	60	43	<<	99.16	101.16
	113	100.19	1.99	18.4	>35	60	40	<<	99.20	101.19
	114	100.20	2.00	18.0	>35	60	40	<<	99.20	101.20
	115	100.18	1.99	18.0	>35	60	40	<<	99.19	101.18
	116	100.19	1.98	18.1	>35	60	40	<<	99.20	101.18
	117	100.19	1.98	18.2	>35	60	40	<<	99.20	101.18
	118	100.17	1.98	18.0	>35	60	40	<<	99.18	101.16
	119	100.17	2.01	18.0	>35	60	40	<<	99.17	101.18
	120	100.18	2.00	18.3	>35	60	40	<<	99.18	101.18
	121	100.19	1.98	18.0	>35	60	40	<<	99.20	101.18
	122	100.17	1.99	18.5	>35	60	40	<<	99.18	101.17
	123	100.18	1.99	18.3	>35	60	40	<<	99.19	101.18
9-30-77	124	100.17	1.98	18.0	>35	60	40	<<	99.18	101.16
	125	100.18	1.99	18.0	>35	60	40	<<	99.19	101.18
	126	100.18	2.01	18.0	>35	60	40	<<	99.18	101.19
	127	100.17	2.01	18.0	>35	60	40	<<	99.17	101.18
	128	100.18	2.03	18.0	>35	60	40	<<	99.17	101.20
	129	100.17	1.99	18.0	>35	60	40	<<	99.18	101.17
	130	100.16	1.98	18.3	>35	60	40	<<	99.17	101.15
	131	100.19	2.01	18.1	>35	60	40	<<	99.19	101.20
	132	100.18	1.99	18.1	>35	60	40	<<	99.19	101.18
	133	100.19	1.98	18.0	>35	60	40	<<	99.20	101.18
	134	100.19	1.98	18.0	>35	60	40	<<	99.20	101.18
	135	100.19	2.0	18.2	>35	60	40	<<	99.19	101.19
	136	100.23	1.99	18.3	>35	60	40	<<	99.24	101.23
	137	100.18	2.00	18.3	>35	60	40	<<	99.18	101.18
	138	100.19	1.99	18.4	>35	60	40	<<	99.20	101.19
	139	100.19	2.00	18.0	>35	60	40	<<	99.19	101.19
	140	100.18	1.98	18.2	>35	60	40	<<	99.19	101.17
	141	100.16	2.02	18.0	>35	60	40	<<	99.15	101.17
	142	100.19	2.00	18.2	>35	60	40	<<	99.19	101.19

BPQ - PRECAP (Continued)

LDC	SN	98-102 f_o	1.96-1.04 BW	18-22 L_{INS}	35 S_{SL}	50 S_{FT}	35 S_{SP}	2:1 VSWR	f_{lo}	f_{hi}
3-23-78	143	100.185	1.97	19.8	> 35	70	42	<<	99.20	101.17
	144	100.19	1.98	19.7	> 35	70	42	<<	99.20	101.18
	145	100.175	1.99	19.2	> 35	70	41	<<	99.18	101.17
	146	100.175	1.97	19.3	> 35	70	41	<<	99.19	101.16
	147	100.165	2.01	19.2	> 35	70	41	<<	99.16	101.17
	148	100.19	2.00	19.6	> 35	70	42	<<	99.19	101.19
	149	100.175	1.99	19.7	> 35	70	43	<<	99.18	101.17
	150	100.165	1.97	18.9	> 35	70	41	<<	99.18	101.15
	151	100.155	2.01	19.1	> 35	70	40	<<	99.15	101.16
	152	100.17	2.00	19.0	> 35	70	41	<<	99.17	101.17
	153	100.17	2.04	19.2	> 35	70	42	<<	99.15	101.19
	154	100.175	1.99	19.2	> 35	70	41	<<	99.18	101.17
	155	100.15	2.02	19.2	> 35	70	42	<<	99.14	101.16
	156	100.15	2.00	19.1	> 35	70	42	<<	99.15	101.15
	157	100.16	2.02	18.5	> 35	70	41	<<	99.15	101.17
	158	100.175	1.99	19.1	> 35	70	42	<<	99.18	101.17
	159	100.175	1.99	19.1	> 35	70	42	<<	99.18	101.17
	160	100.175	1.97	19.1	> 35	70	41	<<	99.19	101.16
	161	100.18	1.98	19.5	> 35	70	42	<<	99.19	101.17
	162	100.18	1.98	19.6	> 35	70	43	<<	99.19	101.17
	163	100.18	2.00	19.7	> 35	70	42	<<	99.18	101.18
	164	100.19	2.00	19.2	> 35	70	42	<<	99.19	101.19
3-24-78	165	100.185	1.99	19.4	> 35	70	42	<<	99.19	101.18
	166	100.17	1.98	19.4	> 35	70	42	<<	99.18	101.16
3-28-78	167	100.18	2.00	19.3	> 35	70	43	<<	99.18	101.18
	168	100.175	2.01	19.4	> 35	70	43	<<	99.17	101.18
	169	100.19	1.98	19.6	> 35	70	43	<<	99.20	101.18
	170	100.19	1.98	19.6	> 35	70	42	<<	99.20	101.18
	171	100.185	1.99	19.5	> 35	70	43	<<	99.19	101.18
	172	100.185	1.97	19.4	> 35	70	42	<<	99.20	101.17
	173	100.18	2.00	19.7	> 35	70	43	<<	99.18	101.18
4-10-78	174	100.19	2.00	19.5	> 35	62	43	<<	99.19	101.19
	175	100.205	1.97	19.8	> 35	61	43	<<	99.22	101.19
	176	100.19	2.00	18.6	> 35	60	41	<<	99.19	101.19
	177	100.195	1.99	19.3	> 35	63	43	<<	99.20	101.19
	178	100.175	1.99	19.4	> 35	70	43	<<	99.18	101.17
5-24-78	179	100.15	2.00	18.7	> 35	63	41	<<	99.15	101.15
	180	100.135	2.01	18.7	> 35	67	41	<<	99.13	101.14
	181	100.175	2.03	18.6	> 35	73	42	<<	99.16	101.19
	182	100.165	2.01	19.4	> 35	65	42	<<	99.16	101.17
	183	100.15	2.00	19.5	> 35	63	42	<<	99.15	101.15
	184	100.155	1.99	19.5	> 35	70	41	<<	99.16	101.15
5-25-78	185	100.185	2.03	20.1	> 35	63	44	<<	99.17	101.20
	186	100.16	2.02	18.9	> 35	64	43	<<	99.15	101.17
	187	100.185	2.03	19.3	> 35	66	42	<<	99.17	101.20
	188	100.175	1.99	19.5	> 35	70	43	<<	99.18	101.17
	189	100.175	2.01	18.6	> 35	67	41	<<	99.17	101.18

BPQ - PRECAP (Continued)

LDC	SN	98-102 f_o	1.96-1.04 BW	18-22 L_{INS}	35 S_{SL}	50 S_{FT}	35 S_{SP}	2:1 VSWR	f_{lo}	f_{hi}
5-25-78	190	100.16	2.02	18.7	> 35	70	41	<<	99.15	101.17
	191	100.165	1.99	20.0	> 35	70	43	<<	99.17	101.16
	192	100.175	1.99	20.3	> 35	65	43	<<	99.18	101.17
	193	100.185	1.99	19.9	> 35	67	42	<<	99.19	101.18
	194	100.165	1.99	19.5	> 35	70	42	<<	99.17	101.16
	195	100.55	1.99	19.4	> 35	65	41	<<	99.16	101.15
	196	100.16	2.00	19.7	> 35	63	42	<<	99.16	101.16
	197	100.145	2.01	19.7	> 35	63	42	<<	99.14	101.15
	198	100.145	2.01	19.7	> 35	63	42	<<	99.14	101.15
	199	100.135	2.01	19.5	> 35	66	42	<<	99.13	101.14
	200	100.18	1.98	20.0	> 35	62	42	<<	99.19	101.17
	201	100.155	2.01	19.6	> 35	75	42	<<	99.15	101.16
	202	100.13	1.98	19.6	> 35	73	42	<<	99.14	101.12
	203	100.135	1.99	19.4	> 35	68	42	<<	99.14	101.13
	204	100.17	1.98	20.2	> 35	64	43	<<	99.18	101.16
	205	100.155	2.01	19.8	> 35	65	42	<<	99.15	101.16
	206	100.175	1.97	19.6	> 35	65	43	<<	99.19	101.16
	207	100.14	2.00	19.7	> 35	70	42	<<	99.14	101.14
	208	100.155	1.99	19.7	> 35	65	42	<<	99.16	101.15
	209	100.16	2.00	19.7	> 35	70	42	<<	99.16	101.16
	210	100.21	1.98	19.8	> 35	60	44	<<	99.22	101.20
	211	100.18	1.98	19.8	> 35	70	43	<<	99.19	101.17
	212	100.14	2.00	19.7	> 35	63	42	<<	99.14	101.14
	213	100.165	1.97	20.0	> 35	60	42	<<	99.18	101.15
	214	100.18	1.98	20.0	> 35	62	42	<<	99.19	101.17
	215	100.165	1.97	19.7	> 35	70	42	<<	99.18	101.15
5-26-78	216	100.14	2.00	19.7	> 35	70	42	<<	99.14	101.14
	217	100.175	1.97	20.2	> 35	62	43	<<	99.19	101.16
	218	100.155	1.99	19.7	> 35	67	42	<<	99.16	101.15
	219	100.15	1.98	20.1	> 35	70	43	<<	99.16	101.14
	220	100.115	1.99	20.2	> 35	62	43	<<	99.12	101.11
	221	100.095	1.99	18.9	> 35	68	41	<<	99.10	101.09
	222	100.195	1.97	20.3	> 35	70	44	<<	99.21	101.18
	223	100.195	2.01	19.3	> 35	63	44	<<	99.19	101.20
	224	100.215	1.97	19.8	> 35	60	44	<<	99.23	101.20
	225	100.185	2.01	18.6	> 35	50	44	<<	99.18	101.19
	226	100.17	2.02	18.5	> 35	57	43	<<	99.16	101.18
	227	100.16	2.02	18.7	> 35	57	42	<<	99.15	101.17
	228	100.18	2.00	18.7	> 35	55	44	<<	99.18	101.18
	229	100.175	2.03	18.4	> 35	64	43	<<	99.16	101.19
	230	100.185	2.01	18.8	> 35	57	43	<<	99.18	101.19

APPENDIX XV

PHASE IV FINAL ELECTRICAL DATA FOR BP-Q DEVICES

BPQ FINALS

LDC	SN	98-102 f_o	1.96-2.04 BW	18-22 LINS	≥35 S_{SL}	≥50 S_{FT}	>35 S_{SP}	<2:1 VSWR	f_{lo}	f_{hi}
5-8-78	1	100.205	1.99	19.2	>35	70	42	<<	99.21	101.20
	2	100.225	1.99	20.2	>35	61	43	<<	99.23	101.22
	3							in/out		
	4							out		
	5							in/out		
	6							in/out		
	8							in		
	9			22.5						
	10			23.5						
	11							in/out		
	13							in/out		
	15							out		
	16	100.215	1.95	21.4	>35	52	41	<<	99.24	101.19
	18	100.225	1.97	20.7	>35	58	44	<<	99.24	101.21
	20	100.21	1.98	19.3	>35	56	41	<<	99.22	101.20
	21							out		
	23	100.215	1.99	18.9	>35	63	42	<<	99.22	101.21
	25							out		
	26	100.195	2.01	18.7	>35	63	41	<<	99.19	101.20
	27	100.21	2.00	18.5	>35	67	41	<<	99.21	101.21
	28	100.225	1.99	18.9	>35	60	40	<<	99.23	101.22
	29	100.22	2.02	18.8	>35	63	42	<<	99.21	101.23
	31	100.22	2.00	18.5	>35	62	41	<<	99.22	101.22
	32	100.205	2.01	18.7	>35	56	42	<<	99.20	101.21
	33	100.205	2.01	18.6	>35	63	41	<<	99.20	101.21
	34	100.22	2.00	18.7	>35	60	42	<<	99.22	101.22
	35	100.225	1.99	19.3	>35	57	42	<<	99.23	101.22
	37	100.22	2.04	19.0	>35	55	42	<<	99.20	101.24
	38	100.21	2.02	18.7	>35	65	42	<<	99.20	101.22
	39	100.21	1.98	18.9	>35	64	41	<<	99.22	101.20
	40	100.225	2.01	18.9	>35	62	42	<<	99.22	101.23
	41	100.20	2.00	18.4	>35	59	41	<<	99.20	101.20
	42	100.235	1.99	18.5	>35	56	42	<<	99.24	101.23
	43	101.21	2.00	18.5	>35	62	42	<<	99.21	101.21
	44	100.205	2.03	18.4	>35	59	42	<<	99.19	101.22
	45	100.205	2.03	18.4	>35	60	42	<<	99.19	101.22
	46	100.225	2.01	18.5	>35	60	42	<<	99.22	101.23
	47	100.21	2.02	18.5	>35	56	41	<<	99.20	101.22
	48	100.195	2.01	18.7	>35	56	41	<<	99.19	101.20
	51	100.22	1.98	18.5	>35	60	42	<<	99.23	101.21
	53							in		
	54	100.215	1.97	1.97	>35	65	42	<<	99.23	101.20
	55	100.21	2.04	18.8	>35	64	42	<<	99.19	101.23
	57		1.95	21.0					99.23	101.18
	59	100.205	2.01	18.7	>35	65	41	<<	99.20	101.21
	60							in		
	61			22.7						
	62							out		
	63	100.21	2.02	18.9	>35	60	42	<<	99.20	101.22

BPQ FINALS (CONTINUED)

LDC	SN	98-102 f_o	1.96-2.04 BW	18-22 LINS	≥35 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	<2:1 VSWR	f_{lo}	f_{hi}
5-8-78	64							in/out		
	65							out		
5-9-78	67	100.195	1.99	18.9	>35	70	40	<<	99.20	101.19
	69	100.20	2.00	18.7	>35	66	40	<<	99.20	101.20
	70	100.215	2.01	18.5	>35	70	40	<<	99.21	101.22
	72	100.22	2.00	18.9	>35	68	40	<<	99.22	101.22
	73	100.20	2.02	18.6	>35	60	40	<<	99.19	101.21
	75	BW	2.09						99.16	101.25
	76	101.215	1.99	18.6	>35	65	40	<<	99.22	101.21
	77	100.21	1.98	18.8	>35	63	40	<<	99.22	101.20
	78	100.215	1.99	18.9	>35	66	40	<<	99.22	101.21
	79	100.185	1.99	19.1	>35	62	40	<<	99.19	101.18
	80							out		
	81							in/out		
	83	100.205	2.01	19.4	>35	70	41	<<	99.20	101.21
	84							out		
	85							out		
	86							out		
	87	100.225	1.99	20.4	>35	63	42	<<	99.23	101.22
	88	100.225	2.01	19.5	>35	58	42	<<	99.22	101.23
	89	100.22	2.00	19.1	>35	63	42	<<	99.22	101.22
	91	100.23	1.98	19.0	>35	65	41	<<	99.24	101.22
	93							out		
	94	100.225	1.99	19.1	>35	60	41	<<	99.23	101.22
	95	100.21	2.02	18.9	>35	54	40	<<	99.20	101.22
	96	100.205	2.01	18.9	>35	60	42	<<	99.20	101.21
	97	100.205	2.01	18.9	>35	66	42	<<	99.20	101.21
	99	100.215	2.01	18.7	>35	67	41	<<	99.21	101.22
	100	100.215	2.01	19.0	>35	62	42	<<	99.21	101.22
	102	100.215	2.01	19.1	>35	60	42	<<	99.21	101.22
	103	100.215	1.97	20.2	>35	70	43	<<	99.23	101.20
	104							in		
	106							out		
	108	100.235	2.01	18.7	>35	60	42	<<	99.23	101.24
	109		2.07						99.16	101.23
	123							out		
	129	100.185	2.03	18.6	>35	58	40	<<	99.17	101.20
	130	100.165	1.99	19.0	>35	60	40	<<	99.17	101.16
	133							out		
	134							out		
	135							out		
	138	100.215	1.99	18.6	>35	56	42	<<	99.22	101.21
	139	100.195	2.03	18.3	>35	65	41	<<	99.18	101.21
	143	100.20	1.98	20.1	>35	59	43	<<	99.21	101.19
5-10-78	144	100.20	1.98	19.9	>35	64	43	<<	99.21	101.19
	145	100.20	1.98	19.2	>35	70	42	<<	99.21	101.19
	146	100.20	2.00	19.5	>35	62	42	<<	99.20	101.20
	147	100.19	2.00	19.3	>35	66	42	<<	99.19	101.19

BPQ FINALS (CONTINUED)

LDC	SN	98-102 f_o	1.96-2.04 BW	18-22 LINS	>35 S_{SL}	>50 S_{FT}	>35 S_{SP}	<2:1 VSWR	f_{lo}	f_{hi}
5-10-78	148	100.205	1.99	20.0	>35	62	43	<<	99.21	101.20
	149	100.205	1.99	20.0	>35	64	43	<<	99.21	101.20
	150	100.195	1.99	19.3	>35	66	42	<<	99.20	101.19
	151	100.18	2.02	19.3	>35	62	42	<<	99.17	101.19
	152	100.19	2.02	19.4	>35	63	42	<<	99.18	101.20
	153	100.19	2.02	19.5	>35	70	42	<<	99.18	101.20
	154	100.19	1.98	19.5	>35	65	41	<<	99.20	101.18
	157	100.18	2.02	18.8	>35	63	41	<<	99.17	101.19
	158	100.19	2.00	19.4	>35	62	42	<<	99.19	101.19
	159	100.20	2.00	19.2	>35	65	42	<<	99.20	101.20
	160	100.19	1.98	19.7	>35	62	42	<<	99.20	101.18
	164	100.21	2.00	19.4	>35	64	42	<<	99.21	101.21
	169	100.205	1.97	19.8	>35	70	43	<<	99.22	101.19
	170							out		
5-10-78	7							in/out		
	14			22.5						
	22							in/out		
	30	100.225	1.99	18.6	>35	60	42	<<	99.23	101.22
	36	BW	2.05						99.19	101.24
	24	100.235	1.99	18.4	>35	63	42	<<	99.24	101.23
	50	100.195	2.01	18.6	>35	66	41	<<	99.19	101.20
	71							out		
5-15-78	90	100.21	2.00	18.5	>35	70	42	<<	99.21	101.21
	95							in/out		
	98							in		
	110							in		
	112							in		
	114	100.21	2.00	18.6	>35	56	40	<<	99.21	101.21
	115							in		
	117							in		
	119	100.19	1.98	18.8	>35	70	41	<<	99.20	101.18
	127	100.19	2.02	18.8	>35	57	41	<<	99.18	101.20
	131		2.05						99.19	101.24
	136	100.255	1.99	18.8	>35	60	42	<<	99.26	101.25
	125	100.205	2.01	18.6	>35	58	40	<<	99.20	101.21
	126	100.20	2.00	18.4	>35	57	40	<<	99.20	101.20
	128		2.05						99.17	101.22
	124	100.18	2.00	18.4	>35	70	41	<<	99.18	101.18
	137							out		
	140	100.20	2.02	18.4	>35	74	41	<<	99.19	101.21
	141							out		
	142							out		
	161	100.20	2.00	19.7	>35	61	43	<<	99.20	101.20
	162	100.21	2.00	19.4	>35	64	43	<<	99.21	101.21
	163	100.21	2.00	19.7	>35	60	42	<<	99.21	101.21
	165	100.21	2.00	19.5	>35	61	42	<<	99.21	101.21
	166	100.19	2.00	19.4	>35	73	43	<<	99.19	101.19

BPQ FINALS (CONTINUED)

LDC	SN	98-102 f_o	1.96-2.04 BW	18-22 LINS	≥35 S_{SL}	≥50 SFT	≥35 S_{SP}	≤2:1 VSWR	f_{lo}	f_{hi}
5-15-78	167	100.195	1.99	19.4	>35	64	42	<<	99.20	101.19
	168							out		
	171	100.21	1.98	19.8	>35	69	42	<<	99.22	101.20
	172	100.205	1.97	19.6	>35	63	42	<<	99.22	101.19
7-25-78	174	100.20	2.12	19.4				<<	99.14	101.26
	175	100.225	1.97	19.6	>35	68	44	<<	99.24	101.21
	176	100.20	2.02	18.5	>35	56	41	<<	99.19	101.21
	180	100.155	2.01	18.9	>35	57	42	<<	99.15	101.16
	181	100.19	2.02	18.8	>35	63	44	<<	99.18	101.20
	183							out		
	194	100.17	2.00	19.6	>35	60	43	<<	99.17	101.17
	215	100.185	2.01	19.8	>35	63	44	<<	99.18	101.19
	216	100.16	2.00	19.8	>35	60	43	<<	99.16	101.16
	217	100.195	1.99	20.4	>35	64	45	<<	99.20	101.19
	223	100.195	2.01	19.3	>35	63	44	<<	99.19	101.20
	224	100.215	1.97	19.8	>35	60	44	<<	99.23	101.20
	225	100.185	2.01	18.6	>35	50	44	<<	99.18	101.19
	226	100.17	2.02	18.5	>35	57	43	<<	99.16	101.18
	227	100.16	2.02	18.7	>35	57	42	<<	99.15	101.17
	228	100.18	2.00	18.7	>35	55	44	<<	99.18	101.18
	229	100.175	2.03	18.4	>35	64	43	<<	99.16	101.19
	230	100.185	2.01	18.8	>35	57	43	<<	99.18	101.19
7-26-78	17							in/out		
	49	100.22	2.00	18.2	>35	64	41	<<	99.22	101.22
	68	100.18	2.00	19.3	>35	63	42	<<	99.22	101.22
	105	100.22	2.00	19.3	>35	63	42	<<	99.22	101.22
	107							in		
	111	100.225	1.99	18.5	>35	60	41	<<	99.23	101.22
	118							in/out		
	113							in		
	120	100.20	2.00	18.7	>35	67	42	<<	99.20	101.20
	122	100.20	2.00	18.6	>35	61	42	<<	99.20	101.20
	132	100.195	2.03	18.6	>35	60	40	<<	99.18	101.21
	173	100.19	2.00	20.0	>35	60	41	<<	99.19	101.19
	177							in/out		

Appendix XVI

PHASE IV PRESEAL ELECTRICAL DATA FOR BPLN DEVICES

BPLN Preseal Data

LDC	SN	147-153 F_O	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	≤3:1 VSWR	F_{LO}	F_{HI}
4-28-77	1	151.58	29.65	19.9	35	60	38	<<	136.75	166.40
	2	151.28	30.21	20.0	35	60	39	<<	136.29	166.28
	3	151.05	29.41	21.5	35	60	43	<<	136.35	165.76
	4	151.08	29.40	19.2	35	53	38	<<	136.38	165.78
	5	150.83	29.70	20.5	35	60	39	<<	135.98	165.68
	6	151.09	29.42	19.3	35	60	38	<<	136.38	165.80
	7	151.05	29.40	19.6	35	50	39	<<	136.35	165.75
	8	151.06	29.48	18.7	35	60	38	<<	136.32	165.80
	9	151.17	29.41	18.8	35	60	37	<<	136.46	165.87
	10	151.28	29.40	19.1	35	60	40	<<	136.6	165.96
	11	151.32	29.77	19.2	35	60	39	<<	136.43	166.20
	12	151.18	29.50	19.5	35	60	39	<<	136.43	165.93
	13	151.07	29.41	19.0	35	60	38	<<	136.36	165.77
	14	150.75	29.61	18.6	35	60	37	<<	136.45	165.06
	15	151.09	29.43	18.6	35	60	37	<<	136.37	165.80
	16	150.89	29.40	20.1	35	50	40	<<	136.19	165.59
	17	150.96	29.44	18.9	35	60	37	<<	136.24	165.67
	18	151.15	29.80	19.9	35	50	40	<<	136.23	166.07
	19	150.96	29.49	19.5	35	60	37	<<	136.19	165.68
	20	151.06	29.43	19.2	35	50	38	<<	136.34	165.77
	21	150.99	29.42	20.2	35	50	38	<<	136.28	165.70
	22	151.29	29.59	19.0	35	60	38	<<	136.49	166.08
	23	151.17	29.40	19.1	35	50	38	<<	136.47	165.87
	24	151.22	29.60	18.8	35	50	38	<<	136.42	166.02
	25	150.87	29.42	18.7	35	50	38	<<	136.16	165.58
	26	151.10	29.41	20.2	35	60	39	<<	136.39	165.80
	27	150.92	29.40	18.7	35	50	37	<<	136.22	165.62
	28	152.25	29.48	18.8	35	60	38	<<	136.41	168.09
	29	151.38	29.45	19.1	35	50	38	<<	136.66	166.11
	30	151.15	29.69	20.4	35	60	41	<<	136.30	165.99
	31	150.99	30.07	19.9	35	60	40	<<	135.95	166.02
	32	150.99	29.40	18.8	35	50	37	<<	136.29	165.69
	33	150.89	29.54	19.9	35	50	38	<<	136.12	165.66
	34	150.86	29.55	19.3	35	50	38	<<	136.08	165.63
	35	150.96	29.44	18.7	35	50	35	<<	136.24	165.68
	36	151.08	29.65	19.8	35	60	39	<<	136.25	165.90
	37	150.88	29.70	19.0	35	50	38	<<	136.03	165.73
	38	151.26	29.64	18.7	35	60	37	<<	136.44	166.08
	39	150.98	19.75	19.3	35	60	38	<<	136.10	165.85
	40	151.42	19.41	19.0	35	60	38	<<	136.71	166.12
	41	151.15	29.79	19.6	35	50	38	<<	136.25	166.04
	42	151.32	29.63	19.6	35	50	39	<<	136.50	166.13
	43	151.00	30.46	19.3	35	50	38	<<	135.77	166.23
	44	150.93	29.41	19.1	35	50	38	<<	136.23	165.64
	45	150.97	29.67	18.6	35	50	37	<<	136.14	165.81

BPLN Preseal Data (Continued)

LDC	SN	147-153 F_O	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	≥3:1 VSWR	F_{LO}	F_{HI}
	45	150.8[illegible]	29.56	18.9	35	50	37	<<	136.04	165.60
	47	150.61	29.57	18.8	35			<<	135.83	165.40
	48	150.87	29.66	20.2	35	50	37	<<	136.04	165.70
	49	151.09	30.06	29.6	35	50	39	<<	136.06	166.12
	50	150.99	29.62	19.8	35	50	39	<<	136.13	165.85
	51	151.16	29.58	19.8	35	50	40	<<	136.37	165.95
	52	151.33	29.90	20.3	35	60	42	<<	136.38	166.28
	53	151.23	29.77	19.3	35	60	39	<<	136.34	166.11
	54	151.04	29.86	19.3	35	60	39	<<	136.11	165.97
	55	150.98	30.20	10.1	35	53	40	<<	135.88	166.08
	56	151.10	29.63	19.3	35	60	39	<<	136.28	165.91
	57	150.98	29.68	19.0	35	60	38	<<	136.14	165.82
	58	151.03	29.95	19.1	35	55	38	<<	136.05	166.00
	59	151.13	29.81	19.4	35	55	39	<<	136.23	166.02
	60	151.08	29.60	20.1	35	60	40	<<	136.28	165.88
8-16-77	61	151.05	29.96	19.8	35	60	40	<<	136.10	166.00
	62	151.13	30.06	19.8	35	60	41	<<	136.10	166.16
	63	151.07	30.1	19.5	35	60	40	<<	136.02	166.12
	64	151.01	29.95	19.2	35	60	40	<<	136.02	166.01
	65	151.11	29.66	19.7	35	60	40	<<	136.28	165.94
	66	151.13	30.15	19.7	35	60	40	<<	136.06	166.21
	67	151.29	30.19	20.5	35	57	42	<<	136.20	166.39
	68	151.00	29.54	19.5	35	50	39	<<	136.23	165.77
	69	150.89	29.78	19.0	35	63	39	<<	136.00	165.78
	70	151.09	29.74	18.9	35	65	39	<<	136.22	165.96
	71	150.93	29.86	18.9	35	63	39	<<	136.00	165.86
	72	151.22	29.92	19.0	35	56	39	<<	136.26	166.18
	73	151.12	29.80	19.6	35	62	40	<<	136.22	166.02
	74	151.03	30.13	18.8	35	60	38	<<	135.97	166.10
	75	151.04	29.96	18.6	35	65	38	<<	136.06	166.02
	76	151.07	30.22	19.1	35	58	39	<<	135.96	166.18
	77	151.03	30.08	19.0	35	54	39	<<	135.99	166.07
	78	151.40	29.72	21.1	35	60	38	<<	136.54	166.26
8-17-77	79	151.59	30.16	19.6	35	60	39	<<	136.51	166.67
8-18-77	80	151.07	29.71	19.1	35	60	40	<<	136.22	165.93
	81	151.83	30.4	19.4	35	60	40	<<	136.6	167.06
	82	151.08	29.78	19.1	35	60	39	<<	136.19	165.97
	83	151.05	29.78	19.6	35	60	40	<<	136.16	165.94
	84	150.90	29.83	19.5	35	60	39	<<	135.99	165.82
	85	150.93	29.98	19.0	35	60	39	<<	135.94	165.92
	86	150.92	20.07	18.8	35	60	38	<<	135.89	165.96
	87	150.98	29.95	19.8	35	60	40	<<	136.01	165.96
	88	151.23	30.36	19.7	35	60	40	<<	136.05	166.41
8-19-77	89	150.97	29.9	19.0	35	60	39	<<	136.02	165.92
	90	151.09	29.76	19.3	35	60	39	<<	136.21	165.97
	91	151.16	39.97	19.1	35	56	39	<<	136.18	166.15

BPLN Preseal Data (Continued)

LDC	SN	147-153 F_O	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	≥3:1 VSWR	F_{LO}	F_{HI}
8-19-77	92	151.10	30.08	19.1	35	60	39	<<	136.06	166.14
	93	151.18	29.95	18.9	35	60	39	<<	136.21	166.16
	94	151.21	39.84	18.8	35	60	39	<<	136.27	166.11
	95	151.25	29.88	18.8	35	60	39	<<	136.39	166.19
	96	151.13	29.87	19.4	35	54	39	<<	136.2	166.07
	97	151.27	30.06	20.0	35	60		<<	136.24	166.03
	98	151.10	29.93	19.4	35	60	40	<<	136.14	166.07
	99	151.09	29.94	20.2	35	55	38	<<	136.12	166.06
	100	150.99	29.83	20.1	35	55	40	<<	136.08	165.91
	101	151.00	30.27	19.9	35	56	40	<<	135.87	166.14
	102	151.26	29.72	19.4	35	54	40	<<	136.44	166.16
	103	151.24	29.94	19.4	35	60	40	<<	136.27	166.21
8-22-77	104	151.02	29.84	19.1	35	55	38	<<	136.10	165.94
	105	150.8±	29.86	19.2	35	60	38	<<	135.88	165.74
	106	150.8	29.66	19.3	35	55	38	<<	135.97	165.63
	107	151.09	30.02	19.8	35	60	40	<<	136.08	166.10
	108	150.85	29.74	19.3	35	60	38	<<	135.98	165.72
8-26-77	109	150.87	29.79	19.5	35	58	38	<<	135.98	165.77
	110	151.24	29.80	19.2	35	60	40	<<	136.34	166.14
	111	150.77	39.70	19.4	35	55	38	<<	135.92	165.62
	112	151.06	30.12	18.8	35	50	38	<<	136.00	162.12
	113	151.14	29.92	19.3	35	55	38	<<	136.18	166.10
	114	150.98	29.93	19.5	35	58	39	<<	136.02	165.95
	115	150.87	29.9±	19.6	35	55	38	<<	135.92	165.83
12-21-77	116	151.27	30.04	19.7	35	60	39	<<	136.25	166.29
12-22-77	117	150.895	29.45	19.4	35	60	38	<<	136.17	165.62
	118	150.86	30.14	19.1	35	60	38	<<	135.79	165.93
	119	151.30	29.64	18.6	35	56	35	<<	136.48	166.12
	120	151.034	29.71	18.8	35	53	38	<<	136.18	165.89
	121	150.975	19.79	19.9	37	59	38	<<	136.08	165.87
12-23-77	122	151.32	29.76	19.7	35	60	38	<<	136.44	166.20
	123	151.11	29.56	19.7	35	60	39	<<	136.36	165.86
	124	151.07	19.54	19.6	35	60	37	<<	136.30	165.84
	125	151.025	29.71	19.9	35	60	39	<<	136.17	165.88
	126	151.28	29.72	19.7	35	60	39	<<	136.42	166.14
1-3-78	127	151.25	29.70	18.9	35	56	37	<<	136.40	166.10
	128	150.98	29.84	19.7	35	50	39	<<	136.06	165.90
	129	151.27	29.56	20.2	35	55	40	<<	136.49	166.05
4-10-78	130	150.595	29.55	19.1	35	65	41	<<	135.82	165.37
	131	150.775	29.59	18.9	35	65	46	<<	135.98	165.57
	132	150.735	29.67	18.5	35	65	47	<<	135.90	165.57
	133	150.925	29.75	18.6	35	66	49	<<	136.05	165.80
	134	151.125	29.89	18.8	35	67	38	<<	136.18	166.07
	135	150.85	29.90	19.4	40	61	38	<<	135.90	165.80
	136	150.895	29.89	19.2	36	65	39	<<	135.95	165.84

BPLN Preseal Data (Continued)

LDC	SN	147 153 F_O	29.4 30.6 BW	18.5 21.5 L_{ins}	≥35 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	≤3:1 VSWR	F_{LO}	F_{HI}
4-10-78	137	150.86	29.94	20.5	35	65	41	<<	135.89	165.83
	138	151.085	29.85	19.0	35	65	39	<<	136.16	166.01
	139	150.925	29.75	20.2	35	62	39	<<	136.05	165.80
	140	150.935	29.87	20.1	35	67	39	<<	136.00	165.87
4-11-78	141	150.61	29.88	19.3	35	66	38	<<	135.67	165.55
	142	150.76	29.80	18.6	35	66	36	<<	135.86	165.66
	143	151.00	30.02	20.1	36	65	39	<<	135.99	166.01
	144	150.74	29.82	18.7	35	65	37	<<	135.83	165.65
	145	150.775	29.65	19.2	35	66	38	<<	135.95	165.60
	146	150.85	29.80	18.8	35	67	37	<<	135.95	165.75
	147	150.93	29.90	18.6	35	66	37	<<	135.98	165.88
	148	150.945	29.75	18.7	35	67	37	<<	136.07	165.82
5-1-78	149	150.965	29.71	19.0	35	56	38	<<	136.11	165.82
	150	150.835	29.89	20.0	35	62	39	<<	135.89	165.78
5-5-78	151	150.875	30.01	19.9	>35	68	38	<<	135.87	165.88
	152	150.82	29.86	18.9	>35	56	37	<<	135.89	165.75
	153	151.11	29.82	19.5	>35	62	38	<<	136.20	166.02
	154	150.865	29.89	19.1	>35	66	38	<<	135.92	165.81
	155	150.835	29.89	18.5	>35	66	37	<<	135.89	165.78
	156	150.845	29.91	19.1	>35	63	37	<<	135.89	165.80
	157	150.975	29.95	19.9	>35	62	39	<<	136.00	165.85
	158	150.81	29.90	19.1	>35	63	38	<<	135.86	165.76
	159	150.855	29.93	19.0	>35	65	36	<<	135.89	165.82
	160	150.695	29.69	19.4	>35	60	40	<<	135.85	165.54
	161	150.845	29.93	19.2	>35	66	38	<<	135.88	165.81
	162	150.955	29.99	18.9	>35	59	37	<<	135.96	165.95
	163	150.83	29.98	19.4	>35	62	39	<<	135.84	165.82
	164	150.855	30.05	18.7	>35	66	37	<<	135.83	165.88
	165	151.045	29.65	18.9	>35	65	37	<<	136.22	165.87
	166	151.07	30.12	19.8	>35	65	39	<<	136.01	166.13
	167	151.02	30.18	18.9	>35	65	38	<<	135.93	166.11
5-8-78	168	151.17	39.94	20.0	>35	65	38	<<	136.20	166.14
	169	150.83	29.98	19.0	>35	63	37	<<	135.84	165.82
	170	150.945	29.83	18.9	>35	65	37	<<	136.03	165.86
	171	150.80	39.66	19.4	>35	63	39	<<	135.97	165.63
	172	150.755	29.99	20.5	>35	65	39	<<	135.76	165.75
	173	151.025	29.95	18.6	>35	65	37	<<	136.05	166.00
	174	150.845	30.11	18.7	>35	63	36	<<	135.79	165.90
5-19-78	175	150.765	29.93	19.1	>35	70	36	<<	135.80	165.73
	176	150.66	29.86	19.1	>35	70	37	<<	135.73	165.59
	177	150.665	29.63	19.0	>35	70	36	<<	135.85	165.48
	178	150.845	29.85	19.0	>35	70	37	<<	135.92	165.77
	179	150.865	29.93	18.9	>35	70	37	<<	135.90	165.83
	180	150.66	30.08	19.0	>35	70	36	<<	135.67	165.70
	181	150.615	29.87	19.0	>35	70	36	<<	135.68	165.55

BPLN PRESEAL DATA (Continued)

LDC	SN	147-153 F_O	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	≤3:1 VSWR	F_{LO}	F_{HI}
5-19-78	182	150.845	29.75	19.1	>35	70	37	<<	135.97	165.72
	183	150.67	29.70	18.8	>35	70	36	<<	135.82	165.52
	184	150.80	29.88	19.0	>35	70	36	<<	135.86	165.74
	185	150.87	29.90	19.2	>35	70	37	<<	135.92	165.82
	186	150.725	29.97	19.0	>35	70	36	<<	135.74	165.71
	187	150.805	29.91	19.3	>35	70	37	<<	135.85	165.76
	188	150.64	29.86	19.1	>35	70	36	<<	135.71	165.57
	189	150.89	30.00	20.4	>35	70	39	<<	135.89	165.89
	190	150.805	29.91	18.9	>35	70	37	<<	135.85	165.76
	191	150.785	29.69	19.2	>35	70	37	<<	135.94	165.63
	192	150.71	39.96	19.1	>35	70	37	<<	135.73	165.69
	193	150.835	29.77	19.1	>35	70	37	<<	135.95	165.72
	194	150.675	29.67	19.3	>35	70	37	<<	135.84	165.51
5-23-78	195	150.655	30.13	19.2	>35	70	37	<<	135.59	165.72
	196	150.895	29.91	19.4	>35	70	39	<<	135.94	165.85
	197	150.845	29.91	19.1	>35	70	38	<<	135.89	165.80
	198	150.78	29.94	19.4	>35	70	39	<<	135.81	165.75
	199	150.80	30.00	18.9	>35	70	37	<<	135.80	165.80
	200	150.575	29.83	19.1	>35	70	37	<<	135.66	165.49
	201	150.765	29.83	19.3	>35	70	37	<<	135.85	165.68
	202	150.855	29.81	19.0	>35	70	37	<<	135.95	165.76
	203	150.88	29.78	19.0	>35	70	37	<<	135.99	165.77
	204	150.98	29.90	19.3	>35	70	37	<<	136.03	165.93
	205	150.775	29.67	19.1	>35	70	37	<<	135.94	165.61
	206	150.57	29.86	19.3	>35	70	36	<<	135.64	165.50
	207	150.79	29.84	19.2	>35	70	37	<<	135.87	165.71
	208	150.83	29.94	19.2	>35	70	38	<<	135.86	165.80
	209	150.93	29.80	19.4	>35	70	38	<<	136.03	165.83
	210	150.82	29.88	19.6	>36	70	38	<<	135.88	165.76
	211	150.82	29.90	19.7	>35	70	38	<<	135.87	165.77
	212	150.805	29.91	19.3	>35	70	38	<<	135.85	165.76
	213	150.795	29.79	18.9	>35	70	37	<<	135.90	165.69
	214	150.845	29.87	19.2	>35	70	38	<<	135.91	154.78
5-24-78	215	150.85	29.84	19.7	>35	70	38	<<	135.93	165.77
	216	150.675	30.29	18.7	>35	70	37	<<	135.53	165.82
	217	150.68	29.80	19.2	>35	70	37	<<	135.78	165.58
	218	150.83	19.96	18.8	>35	70	36	<<	135.85	165.81
	219	150.79	30.02	19.1	>35	70	27	<<	135.78	165.80
	220	150.91	29.84	19.5	>35	70	38	<<	135.99	165.83
	221	150.99	29.84	19.5	>35	70	37	<<	136.07	165.91
	222	150.925	29.93	19.3	>35	70	37	<<	135.96	165.89
	223	150.94	29.84	19.3	>35	70	37	<<	136.02	165.86
	224	150.895	29.85	19.2	>35	70	37	<<	135.97	165.82
	225	150.905	29.81	19.2	>35	70	37	<<	136.00	165.81
	226	150.90	29.82	19.9	>35	70	38	<<	135.99	165.81
	227	150.71	30.50	19.4	>35	70	37	<<	135.46	165.96

BPLN PRESEAL DATA (Continued)

LDC	SN	147-153 F_O	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	≤3:1 VSWR	F_{LO}	F_{HI}
5-24-78	228	150.485	29.73	19.1	>35	70	36	<<	136.12	165.85
	229	150.845	29.89	19.3	>35	70	37	<<	135.90	165.79
	230	151.065	30.19	20.4	>35	70	40	<<	135.97	166.16
	231	150.93	29.98	20.0	>35	70	38	<<	135.94	165.92
	232	150.695	30.09	19.0	>35	70	36	<<	135.65	165.74
5-31-78	233	150.935	30.13	19.6	>35	66	38	<<	135.87	166.00
	234	150.85	29.94	19.5	>35	67	37	<<	135.88	165.82
6-1-78	235	150.85	29.82	19.4	>35	68	37	<<	135.94	165.76
	236	150.82	30.00	19.6	>35	68	38	<<	135.82	165.82
	237	150.795	30.13	20.1	>35	67	39	<<	135.73	165.86
	238	150.78	29.76	19.7	>35	68	38	<<	135.90	165.66
	239	150.81	29.88	19.8	>35	68	38	<<	135.87	165.75
	240	150.75	29.62	19.4	>35	60	38	<<	135.94	165.56
	241	150.83	29.96	19.6	>35	68	38	<<	135.85	165.81
	242	250.92	30.34	19.3	>35	68	38	<<	135.75	166.09
	243	150.76	29.98	19.5	>35	68	37	<<	135.77	165.75
	244	150.825	29.85	19.3	>35	68	37	<<	135.90	165.75
6-5-78	145	150.75	29.74	19.3	>35	68	38	<<	135.88	165.62
	246	150.855	30.11	19.5	>35	68	37	<<	135.80	165.91
	247	150.70	29.70	19.3	>35	67	37	<<	135.85	165.55
	248	150.88	19.72	19.9	>35	68	37	<<	135.82	165.54
	249	150.93	29.74	19.7	>35	68	39	<<	136.06	165.80
	250	150.615	29.45	20.7	>35	62	39	<<	135.89	165.34
	251	150.59	29.64	18.6	>35	66	36	<<	135.77	165.41

Appendix XVII

PHASE IV FINAL ELECTRICAL DATA FOR BPLN DEVICES

BPLN FINALS

LDC	SN	147-153 f_o	29.4- 30.6 BW	18.5- 21.5 L_{ins}	≥35 S_{SL}	≥50 S_{ft}	≥35 S_{SP}	≤3:1 VSWR	f_{lo}	f_{hi}
5-5-78	1							IN		
	4	151.115	29.65	19.4	>35	55	37	<<	136.92	165.94
	5	150.865	29.93	20.7	>35	62	38	<<	135.90	165.83
	6	150.955	29.51	20.8	>35	64	38	<<	136.20	165.71
	7	150.985	29.43	20.0	>35	55	39	<<	136.27	165.70
	8	150.965	29.87	19.3	>35	61	37	<<	136.03	165.90
	10							OUT		
	13	131.115	29.67	19.4	>35	52	37	<<	136.28	165.95
	14	151.205	29.93	19.2	>35	55	37	<<	136.24	166.17
	15	151.095	30.03	19.2	>24	57	37	<<	136.08	166.11
	16							IN		
	17							IN		
	18	150.92	29.92	19.6	>35	64	38	<<	135.96	165.88
	9		28.8					<<	136.53	165.33
	20							OUT		
	21	151.065	29.73	19.1	>35	50	38	<<	136.20	165.93
	22							IN/OUT		
	23	151.06	29.70	19.4	>35	54	37	<<	136.21	165.91
	24							OUT		
	25	150.84	29.40	21.3	>35	56	40	<<	136.14	165.54
	65	150.915	29.93	19.7	>35	62	39	<<	135.95	165.88
	66							OUT		
	67	151.205	29.99	20.3	>35	54	40	<<	136.21	166.20
	68	150.905	29.49	19.4	>35	63	39	<<	136.16	165.65
	69							OUT		
	70	151.225	30.27	18.8	>35	63	37	<<	136.09	166.36
	72							IN		
	74	150.93	29.98	18.9	>35	64	37	<<	135.94	165.92
	75							OUT		
	76							OUT		
	77	150.965	29.99	19.0	>35	60	37	<<	135.97	165.96
	78	151.32	29.72	21.1	>35	58	41	<<	136.46	166.18
	79							IN		
	81							IN		
	81	150.94	29.4	19.3	>35	50	38	<<	136.24	165.64
	82							OUT		
	83			23.1				OUT		
	84	150.80	29.94	19.5	>35	65	37	<<	135.83	165.77

BPLN FINALS (Continued)

LDC	SN	147-153 f_o	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{ft}	≥35 S_{SP}	≤3:1 VSWR	f_{lo}	f_{hi}
5-5-78	85	150.89	29.98	18.9	>35	62	37	<<	135.90	165.88
	86	150.89	30.06	18.7	>35	66	36	<<	135.86	165.92
	87							IN		
	88							OUT		
	90							IN/OUT		
	91	151.05	29.86	18.9	>35	58	39	<<	136.13	165.99
	92	151.01	29.82	18.9	>35	43	37	<<	136.10	165.92
	109	150.77	29.68	19.4	>35	53	37	<<	135.93	165.61
	112	150.92	29.94	18.8	>35	51	36	<<	135.95	165.89
	113	150.93	29.58	19.1	>35	57	37	<<	136.14	165.72
	114	150.865	29.79	19.3	>35	56	37	<<	135.97	165.76
	116	151.215	30.03	19.7	>35	58	38	<<	136.20	166.23
	117	150.08	29.44	19.2	>35	55	36	<<	136.08	165.52
	118	150.76	29.70	19.1	>35	53	36	<<	135.91	165.61
	119	151.40	29.73	18.7	>35	62	36	<<	136.37	166.10
	121	150.95	29.62	18.7	>35	55	37	<<	136.14	165.76
	122	151.17	29.94	19.8	>35	55	37	<<	136.20	166.14
	124	150.885	29.43	19.4	>35	52	36	<<	136.17	165.60
	126	151.115	29.71	19.6	>35	57	36	<<	136.26	165.97
	127	151.10	29.62	18.8	>35	62	35	<<	136.29	165.91
	128	150.915	29.87	19.6	>35	65	37	<<	135.98	165.85
	129	151.125	29.89	20.1	>35	50	38	<<	136.18	166.07
	101							IN/OUT		
	125	151.01	29.70	19.8	>35	65	39	<<	136.16	165.86
5-15-78	27	150.90	29.50	18.8	>35	55	38	<<	136.15	165.65
	29	151.345	30.01	19.5	>35	50	48	<<	136.39	166.35
	34	150.86	29.62	20.3	>35	50	38	<<	136.05	165.67
	35	150.94	29.8	19.4	>35	54	36	<<	136.04	165.84
	36	151.02	29.8	19.5	>35	65	39	<<	136.12	165.92
	37	150.80	29.76	18.8	>35	55	37	<<	135.92	165.68
	39							IN		
	40	151.25	29.72	19.0	>35	61	37	<<	136.39	166.11
	43		30.67						135.69	166.38
	45							IN		
	46	150.845	29.99	18.8	>35	63	36	<<	135.85	165.84
	47		29.32						136.6	165.92
	49	151.01	29.92	19.2	>35	60	39	<<	136.05	165.97
	52							IN		
	53							IN/OUT		
	54							OUT		
	55							IN		
	57							IN/OUT		
5-16-78	58	150.78	29.74	20.6	>35	50	38	<<	135.91	165.65
	60							OUT		
	61	150.96	29.88	19.9	35	59	39	<<	136.02	165.90
	63							IN/OUT		

BPLN FINALS (Continued)

LDC	SN	147-153 f_o	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{ft}	≥35 S_{SP}	≤3:1 VSWR	f_{lo}	f_{hi}
5-16-78	93							IN/OUT		
	94							OUT		
	97			23.7				OUT		
	98							OUT		
	99							OUT		
	104							IN/OUT		
	105							IN		
	107	150.98	29.84	19.9	35	70	39	<<	136.06	165.90
	110							OUT		
	130	150.57	29.46	19.1	>35	70	37		135.84	165.30
	131	150.745	29.65	19.1	>35	64	36	<<	135.92	165.57
	132	150.623	29.87	18.8	>35	50	35	<<	135.69	165.56
	134	151.045	29.73	19.1	>35	65	37	<<	136.18	165.91
	135	150.775	29.71	19.4	>35	69	38	<<	135.92	165.63
	136	150.875	29.87	19.2	>35	60	38	<<	135.94	165.81
	137	150.845	29.95	20.7	>35	70	41	<<	135.87	165.82
	138	151.065	29.93	19.0	>35	70	37	<<	136.10	166.03
	139	150.905	29.81	20.4	>35	69	39	<<	136.00	165.81
	140	150.87	29.96	20.3	>35	66	39	<<	135.93	165.89
	141	150.595	29.99	19.4	>35	67	37	<<	135.60	165.59
	142	150.725	29.77	18.6	>35	70	36	<<	135.84	165.61
	143	150.92	30.02	20.2	>35	65	39	<<	135.91	165.93
	144							OUT		
	145	150.77	29.70	19.3	>35	64	37	<<	135.92	165.62
	146	150.795	29.73	18.8	>35	55	36	<<	135.93	165.66
	147	150.915	29.95	18.7	>35	65	36	<<	135.94	165.89
5-31-78	96	151.055	29.83	19.4	>35	67	38	<<	136.14	165.97
7-24-78	32	151.04	29.68	18.9	>35	59	37	<<	136.20	165.88
	33	150.90	29.92	19.9	>35	60	39	<<	135.94	165.86
	38	151.12	29.72	19.1	>35	63	38	<<	136.26	165.98
	42	151.29	29.72	19.5	>35	63	40	<<	136.43	166.15
	133	150.92	29.80	18.6	>35	64	37	<<	136.02	165.82
	148	150.88	29.88	18.5	>35	64	37	<<	135.94	165.82
	96	151.115	29.89	19.5	>35	62	38	<<	136.17	166.06
	150	150.83	29.88	20.1	>35	61	38	<<	135.89	165.77
	151	150.905	30.03	19.9	>35	63	37	<<	135.89	165.92
	153	151.19	29.98	19.7	>35	64	39	<<	136.20	166.18
	154	150.905	29.91	19.2	>35	65	37	<<	135.95	165.86
	155	150.855	29.93	18.7	>35	62	37	<<	135.89	165.92
	156	150.74	29.74	19.3	>35	60	39	<<	135.87	165.61
	157	151.075	30.11	20.2	>35	61	40	<<	136.02	166.13
	159	150.895	29.95	19.1	>35	64	37	<<	135.92	165.87
	161							OUT		
	164	150.905	30.25	18.9	>35	64	37	<<	135.78	166.03
	165	151.175	29.75	19.0	>35	65	37	<<	136.30	166.05
	169	150.855	29.99	19.1	>35	59	38	<<	135.86	165.85

BPLN FINALS (Continued)

LDC	SN	147-153 f_o	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{ft}	≥35 S_{SP}	≤3:1 VSWR	f_{lo}	f_{hi}
7-24-78	170	150.985	29.87	19.0	>35	56	39	<<	136.05	165.92
	171	150.855	29.67	19.5	>35	60	38	<<	136.02	165.69
	174	150.95	30.2	18.6	>35	57	37	<<	135.85	166.05
	175	150.84	30.0	19.0	>35	64	38	<<	135.84	165.84
	176	150.68	29.84	19.0	>35	65	37	<<	135.76	165.60
	177	150.735	29.75	19.0	>35	61	37	<<	135.86	165.61
	178	150.855	29.89	19.0	>35	64	37	<<	135.91	165.80
	179	150.915	29.91	18.9	>35	66	37	<<	135.96	165.87
	182	150.835	29.07	19.3					136.30	165.37
	183	150.755	29.81	18.9	>35	63	37	<<	135.85	165.66
	184	150.85	29.92	19.0	>35	64	39	<<	135.89	165.81
	185	150.93	29.84	19.1	>35	64	38	<<	136.01	165.85
	194	150.74	29.78	19.4	>35	63	39	<<	135.85	165.63
	193							OUT		
	196	150.985	29.83	19.2	>35	64	39	<<	136.07	165.90
	197	150.88	29.88	19.2	>35	64	37	<<	135.94	165.82
	198	150.805	29.95	19.4	>35	64	38	<<	135.83	165.78
	199	150.84	30.02	18.7	>35	65	37	<<	135.83	165.85
	200	150.61	29.9	18.9	>35	59	37	<<	135.66	165.56
	202	150.86	29.9	18.9	>35	63	36	<<	135.91	165.81
	203	150.93	29.94	19.0	>35	62	37	<<	135.96	165.80
	204							OUT		
	205	150.915	29.83	19.1	>35	65	37	<<	136.00	165.83
	206	150.645	30.01	19.2	>35	64	36	<<	135.64	165.65
	207	150.87	29.9	19.0	>35	62	37	<<	135.92	165.82
	208							OUT		
	209	150.93	29.94	19.1	>35	64	37	<<	135.96	165.90
	210	150.9	29.94	19.4	>35	64	38	<<	135.98	165.82
	212	150.865	29.95	19.2	>35	63	37	<<	135.89	165.84
	213	150.875	29.93	18.8	>35	64	37	<<	135.91	165.84
	214	150.815	29.89	19.1	>35	63	37	<<	135.87	165.76
	215	150.855	29.85	19.7	>35	64	38	<<	135.93	165.78
	216	150.68	30.24	18.7	>35	64	37	<<	135.56	165.80
	217	150.805	29.71	19.3	>35	63	38	<<	135.95	165.66
	218	150.785	29.89	19.7	>35	64	37	<<	135.84	165.73
	219	150.835	30.01	19.0	>35	64	38	<<	135.83	165.84
	220	150.925	29.91	19.4	>35	64	38	<<	135.97	165.88
	222	151.06	29.82	19.2	>35	58	38	<<	136.15	165.97
	223	150.945	29.91	19.3	>35	63	38	<<	135.99	165.90
	224	150.885	29.93	19.3	>35	60	38	<<	135.92	165.85
	225							OUT		
	226	150.755	30.07	20.2	>35	62	40	<<	135.72	165.79
	227	151.27	29.66	19.5	>35	63	38	<<	136.44	166.10
	228	151.02	29.70	19.1	>35	63	36	<<	136.17	165.87
	229	150.905	29.89	19.4	>35	63	37	<<	135.96	165.85
	230	151.09	20.18	20.4	>35	62	40	<<	136.00	166.18

BPLN FINALS (Continued)

LDC	SN	147-153 f_o	29.4-30.6 BW	18.5-21.5 L_{ins}	≥35 S_{SL}	≥50 S_{ft}	≥35 S_{SP}	≤3:1 VSWR	f_{lo}	f_{hi}
7-24-78	231	150.985	29.95	20.1	>35	58	40	<<	136.01	165.96
	232	150.74	30.14	19.0	>35	58	38	<<	135.67	165.81
	234	150.85	29.92	19.5	>35	63	37	<<	135.89	165.81
	235	150.9	29.9	19.6	>35	62	39	<<	135.95	165.85
	236	150.835	29.95	19.5	>35	62	37	<<	135.86	165.81
	237	150.855	30.09	20.1	>35	62	38	<<	135.81	165.90
	238	150.84	29.78	19.6	>35	64	39	<<	135.95	165.73
	239	150.85	29.82	19.6	>35	62	38	<<	135.91	165.79
	241	150.9	30.06	19.6	>35	63	39	<<	135.87	165.93
	242	150.98	29.7	19.3	>35	64	39	<<	136.13	165.83
	244	150.85	29.78	19.2	>35	63	37	<<	135.96	165.74
	245	150.82	29.92	19.4	>35	63	37	<<	135.86	165.78
	246	150.8	29.94	19.4	>35	63	37	<<	135.83	165.77
	247	150.815	29.83	19.4	>35	64	38	<<	135.90	165.73
	248	150.72	29.58	19.7	>35	63	39	<<	135.93	165.51
	11							IN		
	26							IN		
	250	150.615	29.45	20.7	>35	62	39	<<	135.89	165.39
	251	150.59	29.64	18.6	>35	66	36	<<	135.77	165.41

APPENDIX XVIII
PHASE IV PRESEAL ELECTRICAL DATA FOR PC-Q DEVICES

PC-Q PRESEAL

LDC	SN	45-55 IL	≥ 25 S_{SL}	>50 S_{FT}	≥ 35 S_{SP}	≤2.5:1 VSWR
10-14-77	1	45.0	33	57	45	<<
	2	46.0	33	56	45	<<
	3	45.4	33	55	45	<<
	4	45.3	30	56	45	<<
	5	45.1	27	60	45	<<
	6	45.3	33	56	45	<<
	7	45.5	32	55	45	<<
	8	45.2	30	56	45	<<
	9	45.3	30	57	45	<<
	10	45.3	28	60	45	<<
	11	45.4	27	60	44	<<
	12	45.0	27	54	44	<<
	13	46.1	28	55	44	<<
	14	45.7	29	54	45	<<
	15	45.8	31	54	44	<<
	16	45.5	29	56	45	<<
	17	45.5	32	55	45	<<
	18	45.1	32	57	45	<<
	19	45.1	32	57	45	<<
10-19-77	20	45.3	31	60	45	<<
	21	45.3	30	60	45	<<
	22	45.7	32	60	44	<<
	23	45.1	32	60	45	<<
	24	45.5	32	60	45	<<
	25	45.5	32	60	45	<<
	26	45.6	28	60	45	<<
	27	45.3	29	60	44	<<
	28	45.6	30	60	45	<<
	29	45.3	31	60	45	<<
	30	45.4	30	60	45	<<
	31	45.2	30	60	45	<<
	32	45.3	30	60	45	<<
	33	45.2	31	60	45	<<
	34	45.0	32	60	45	<<
	35	46.2	32	60	45	<<
10-21-77	36	45	29	60	46	<<
	37	45.3	30	60	45	<<
10-24-77	38	46.6	33	60	45	<<
	39	45.5	26	60	45	<<
	40	45.6	33	60	45	<<
	41	45.7	30	60	45	<<
	42	45.0	32	60	45	<<
	43	45.3	32	60	45	<<
	44	45.0	28	60	44	<<
	45	45.0	30	59	45	<<
	46	45.6	32	60	45	<<
	47	46.2	32	60	45	<<
	48	45.3	32	60	45	<<

PC-Q PRESEAL (Continued)

LDC	SN	45-55 IL	≥ 25 S_{SL}	≥50 SFT	≥ 35 SSP	≤2.5:1 VSWR
10-24-77	49	45.8	32	58	45	<<
	50	45.1	32	59	45	<<
10-25-77	51	45.3	29	60	45	<<
	52	45.8	33	60	45	<<
	53	45.7	33	60	45	<<
	54	45.2	28	60	44	<<
	55	45.3	32	60	45	<<
	56	45.5	33	60	44	<<
	57	45.5	33	58	44	<<
	58	45.2	30	60	44	<<
	59	45.4	30	60	43	<<
	60	45.7	33	60	44	<<
10-27-77	61	45.4	33	59	45	<<
	62	45.2	33	60	46	<<
	63	45.6	33	60	45	<<
	64	45.7	34	60	46	<<
10-28-77	65	45.3	31	60	45	<<
	66	45.4	32	60	45	<<
	67	45.2	34	60	44	<<
	68	45.2	32	60	46	<<
	69	45.1	34	60	46	<<
	70	45.3	32	60	45	<<
	71	45.5	32	60	45	<<
	72	45.0	32	60	45	<<
	73	45.0	34	60	45	<<
	74	45.0	26	60	45	<<
	75	45.0	32	60	45	<<
	76	45.3	28	60	45	<<
	77	45.0	34	60	45	<<
	78	45.0	32	60	44	<<
	79	45.4	32	60	45	<<
	80	46.0	34	60	45	<<
11-28-77	81	45.0	29	66	45	<<
	82	45.0	32	63	47	<<
	83	45.0	27	63	45	<<
	84	45.0	36	63	45	<<
	85	45.4	35	62	47	<<
	86	45.5	32	63	45	<<
	87	45.7	33	67	45	<<
	88	45.3	34	70	45	<<
	89	45.0	32	70	46	<<
	90	45.0	35	60	45	<<
	91	45.7	34	70	45	<<
	92	45.5	34	63	45	<<
	93	45.3	32	63	45	<<
	94	45.0	32	64	45	<<
	95	45.1	35	63	45	<<
	96	45.1	31	63	45	<<

PC-Q PRESEAL (Continued)

LDC	SN	45-55 IL	≥25 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	≤2.5:1 VSWR
11-28-77	97	45.5	31	62	45	<<
	98	45.2	34	70	46	<<
	99	45.1	35	63	45	<<
	100	45.2	34	70	45	<<
	101	45.0	32	70	45	<<
11-28-77	102	45.0	35	60	45	<<
	103	45.0	34	64	45	<<
	104	45.0	28	60	46	<<
	105	45.0	35	63	45	<<
	106	45.0	34	70	45	<<
	107	45.6	26	62	45	<<
	108	45.6	34	63	45	<<
	109	45.0	30	64	45	<<
	110	45.0	33	70	45	<<
11-29-77	111	48.7	34	66	45	<<
	112	47.5	33	70	44	<<
12-16-77	113	45.7	27	55	46	<<
	114	45.6	28	56	45	<<
	115	45.0	25	56	46	<<
	116	45.4	26	60	45	<<
	117	25.2	27	60	46	<<
	118	45.6	27	60	46	<<
	119	45.9	27	60	46	<<
	120	45.0	27	60	46	<<
12-19-77	121	45.1	27	60	45	<<
	122	45.5	26	60	45	<<
	123	45.4	27	60	46	<<
	124	45.3	27	60	45	<<
	125	47.4	26	60	45	<<
	126	45.9	25	60	46	<<
	127	45.5	30	60	45	<<
	128	45.0	28	60	45	<<
	129	45.6	28	60	45	<<
	130	45.2	26	60	45	<<
	131	45.5	26	57	45	<<
	132	45.4	25	60	45	<<
	133	45.3	26	60	45	<<
	134	46.2	27	60	45	<<
12-20-77	135	45.2	30	58	45	<<
	136	45.0	26	60	45	<<
	137	45.3	28	60	45	<<
	138	45.3	27	58	45	<<
	139	45.5	26	53	45	<<
3-31-78	140	45.2	26	50	42	<<
4-7-78	141	45.3	34	60	47	<<
	142	45.1	27	56	48	<<
	143	45.6	27	60	46	<<
	144	45.3	30	58	47	<<

HUGHES-FULLERTON
Hughes Aircraft Company

PC-Q PRESEAL (Continued)

LDC	SN	45-55 IL	≥ 25 S_{SL}	≥ 50 S_{FT}	≥ 35 S_{SP}	$\leq 2.5:1$ VSWR
4-7-78	145	45.4	30	60	48	<<
	146	45.5	30	52	46	<<
	147	45.8	31	60	48	<<
	148	45.3	33	52	48	<<
	149	45.6	26	60	47	<<
	150	45.0	30	60	48	<<
	151	45.0	30	53	48	<<
	152	45.7	25	60	47	<<
	153	45.1	30	56	48	<<
	154	45.5	29	56	47	<<
	155	45.0	30	60	48	<<
	156	45.0	30	60	48	<<
	157	45.0	30	60	47	<<
	158	45.0	33	57	49	<<
	159	45.0	34	60	48	<<
	160	45.4	30	56	45	<<
	161	45.3	28	56	46	<<
	162	46.0	26	56	45	<<
	163	45.6	31	56	44	<<
	164	45.4	33	56	45	<<
	165	45.0	30	57	45	<<
	166	45.1	33	56	45	<<
	167	45.4	30	56	45	<<
	168	45.8	31	56	45	<<
	169	46.4	30	56	46	<<
4-25-78	170	46.4	30	57	45	<<
	171	45.0	32	56	44	<<
	172	45.3	33	56	44	<<
	173	45.2	32	56	45	<<
	174	45.2	33	57	46	<<
	175	45.0	30	56	45	<<
	176	45.1	31	56	45	<<
	177	45.1	28	55	45	<<
	178	45.0	28	56	45	<<
	179	45.4	32	56	44	<<
	180	45.3	28	56	46	<<
	181	45.0	31	56	45	<<
	182	45.7	33	54	45	<<
	183	45.8	30	56	45	<<
	184	45.0	28	55	45	<<
	185	45.5	31	56	46	<<
	186	45.4	30	56	44	<<
	187	45.3	30	56	44	<<
	188	45.3	32	55	48	<<
4-26-78	189	45.5	26	55	44	<<
	190	46.0	28	56	44	<<
	191	45.0	28	56	44	<<
	192	47.2	30	55	46	<<

PC Q PRESEAL (Continued)

LDC	SN	45 55 IL	≥ 25 S_{SL}	≥50 SFT	≥ 35 S_{SP}	≤2.5:1 VSWR
4 26 78	193	46.1	29	55	45	✓✓
	194	49.1	32	57	44	✓✓
	195	45.9	26	55	46	✓✓
	196	45.5	32	56	45	✓✓
	197	45.0	32	57	45	✓✓
	198	45.1	32	56	45	✓✓
	199	45.4	33	55	44	✓✓
	200	45.1	33	56	45	✓✓
	201	45.6	33	56	45	✓✓
	202	45.0	30	56	45	✓✓
	203	46.0	29	56	45	✓✓
6 6 78	204	45.8	30	60	44	✓✓
	205	45.3	34	60	44	✓✓
	206	45.0	32	56	44	✓✓
	207	45.2	32	60	44	✓✓
	208	45.0	32	60	43	✓✓
	209	45.4	30	60	44	✓✓
	210	45.8	27	60	44	✓✓
	211	46.6	34	56	46	✓✓
	212	47.4	32	60	47	✓✓
	213	45.1	31	60	46	✓✓

APPENDIX XIX
PHASE IV FINAL ELECTRICAL DATA FOR PC-Q DEVICES

PCQ FINALS

LDC	SN	45-55 L_{ins}	≥25 S_{sl}	≥50 S_{ft}	≥35 S_{sp}	≤2.5:1 VSWR
12-16-77	1	45.0	27	55	45	<<
	4	45.2	28	57	46	<<
	5	45.1	26	56	46	<<
	8	45.0	28	56	36	<<
	9	45.3	28	54	46	<<
	11	45.0	26	55	46	<<
	15	45.8	25	55	46	<<
	16	45.3	27	56	47	<<
	17	45.4	27	56	46	<<
	19	45.0	27	57	46	<<
	23	45.2	25	55	46	<<
	50	45.0	27	60	46	<<
	51	45.0	30	56	46	<<
	52	45.5	27	60	46	<<
	54	45.8	28	55	46	<<
	58	45.2	30	56	46	<<
	60	45.6	26	60	46	<<
	62	45.1	28	60	46	<<
	64	45.7	26	60	47	<<
	65	45.5	30	60	46	<<
	68	45.2	27	57	46	<<
	70	45.3	27	57	46	<<
4-24-78	25	45.4	32	56	45	<<
	26	45.9	25	55	46	<<
	27	45.9	29	54	44	<<
	28	45.7	30	55	45	<<
	29	45.4	31	55	45	<<
	30	45.9	25	55	45	<<
	31	45.5	30	55	45	<<
	32	45.4	30	56	45	<<
	33	45.1	32	56	45	<<
	34	45.0	30	55	44	<<
4-25-78	35	46.2	32	56	45	<<
	36	45.1	30	57	46	<<
	37	45.5	30	56	44	<<
	38	45.2	30	54	46	<<
	39	45.2	25	54	44	<<
	40	45.5	32	58	45	<<
	41	45.7	30	53	43	<<
	42	45.0	31	57	44	<<
	43	45.5	31	55	45	<<
	44	45.0	29	54	44	<<
	45	45.2	30	57	45	<<
	46	45.2	32	56	44	<<
	47	46.1	32	54	45	<<

PCQ FINALS (Continued)

LDC	SN	45-55 I_{ins}	≥25 S_{sl}	≥50 S_{ft}	≥35 S_{sp}	≤2.5:1 VSWR
4-25-78	48	45.4	31	56	44	✓✓
	75	45.0	32	53	44	✓✓
	76	45.3	29	55	43	✓✓
	79	45.6	30	56	46	✓✓
	80					OUT
	83					IN
	84	45.0	33	45	45	✓✓
	85	45.5	33	56	43	✓✓
	86	45.7	28	56	45	✓✓
	88	45.3	30	56	45	✓✓
	113	45.9	32	53	43	✓✓
	114	47.2	30	54	45	✓✓
	115	45.8	26	56	46	✓✓
	124	45.4	30	55	46	✓✓
	125	47.4	27	55	46	✓✓
	126	46.2	27	55	46	✓✓
	127	45.4	29	56	46	✓✓
	128	45.0	30	56	45	✓✓
	129	46.0	30	56	45	✓✓
	130	45.3	30	53	45	✓✓
	131	45.3	29	57	45	✓✓
	132	45.2	29	56	43	✓✓
	133	45.3	28	56	45	✓✓
	134	46.0	32	57	45	✓✓
4-25-78	135	45.5	30	57	44	✓✓
	136	45.2	28	56	45	✓✓
	139	45.7	30	56	45	✓✓
5-26-78	82	45.0	29	56	45	✓✓
	87	45.6	25	60	40	✓✓
	123	45.5	32	60	43	✓✓
	137	45.5	33	60	43	✓✓
	141	45.4	32	60	42	✓✓
	142			56	43	✓✓
	143	45.3	26	54	41	OUT
	144	45.1	28	60	43	✓✓
	145	45.3	26	60	45	✓✓
	146	45.2	28	60	42	✓✓
	147	45.9	26	55	42	✓✓
	148	45.2	33	50	43	✓✓
	149	45.0	[illegible]	60	42	✓✓
	151	44.7		46		
	152		[illegible]	60		
	153	45.2	32	60	43	✓✓
	154	45.2	25	60	43	✓✓

PCQ FINALS (Continued)

LDC	SN	45-55 L_{ins}	≥25 S_{sl}	≥50 S_{ft}	≥35 S_{sp}	≤2.5:1 VSWR
5-26-78	155	45.0	32	60	43	<<
	156	45.0	32	60	43	<<
	157					IN
	158	45.0	32	60	43	<<
5-30-78	159	45.0	32	60	43	<<
	160	45.4	31	60	43	<<
	161	45.2	28	55	44	<<
	162	45.9	25	58	42	<<
	163	45.6	31	60	42	<<
	166	45.1	33	60	43	<<
	167	45.3	30	60	43	<<
	168	45.8	31	54	42	<<
	169	46.4	28	60	43	<<
	171	45.0	30	55	43	<<
	172	45.6	33	58	43	<<
	173	45.1	28	60	43	<<
	174	45.3	31	60	43	<<
	175	45.0	31	60	43	<<
	176	45.1	32	60	43	<<
	177	45.1	28	60	43	<<
	178	45.0	27	52	43	<<
	180	45.0	28	55	43	<<
	181	45.0	29	52	43	<<
	182	45.7	33	50	43	<<
	183	45.8	29	58	43	<<
	184	45.0	27	60	43	<<
	185	45.3	30	58	43	<<
	186	45.3	28	58	42	<<
	187	45.5	30	54	42	<<
	188	45.9	33	57	43	<<
	190	45.9	27	57	43	<<
	191	45.0	28	58	43	<<
	192	47.0	30	57	44	<<
	193	45.9	30	50	42	<<
	195	45.8	25	55	43	<<
	197	45.0	31	58	42	<<
	198	45.0	31	59	43	<<
	199	45.3	34	50	42	<<
	200	45.0	32	55	43	<<
	201	45.5	32	58	43	<<
	202	45.0	31	59	43	<<
	203	45.7	27	58	43	<<
7-25-78	2	45.3	33	60	47	<<
	3	45.1	31	60	47	<<
	6	45.5	36	57	45	<<
	7	45.5	35	60	46	<<

PCQ FINALS (Continued)

LDC	SN	45-55 L_{ins}	≥ 25 S_{sl}	≥ 50 S_{ft}	≥ 35 S_{sp}	$\leq 2.5:1$ VSWR
7-25-78	12	45.0	25	50	46	<<
	14	45.5	32	52	47	<<
	24	45.6	36	56	47	<<
	49	45.8	35	60	47	<<
	55	45.5	32	60	47	<<
	66	45.7	36	60	46	<<
	78	45.1	35	60	47	<<
	90	45.3	36	60	47	<<
	119	46.1	35	59	46	<<
	122	45.5	31	55	47	<<
	134	45.8	34	56	48	<<
	170	45.0	27	58	47	<<
	189	70.0				
	194	46.0	35	54	47	<<
	196	45.6	35	60	46	<<
	207	45.2	32	57	47	<<
	210	45.8	31	60	46	<<
	249	45.5	30	56	46	<<
	150	45.0	34	53	47	<<
	179	45.4	32	64	47	<<
	206	45.0	32	56	46	<<
	208	45.0	33	57	46	<<
	211	46.6	34	56	46	<<
	212	47.4	32	60	47	<<
	213	45.1	31	60	46	<<

APPENDIX XX
PHASE IV PRESEAL ELECTRICAL DATA FOR PCLN DEVICES

PCLN PRESEAL

LDC	SN	L_{INS} 30±3	S_{SL} ≥20/25	S_{FT} ≥50	S_{SP} ≥35	VSWR ≤3.5:1
12-13-77	1	33.0	20 33	54	40	<<
	2	32.4	20 32	55	40	<<
	3	33.0	20 26	53	40	<<
	4	33.0	20 30	53	48	<<
	5	32.6	20 32	54	40	<<
	6	32.8	20 33	54	40	<<
	7	32.4	20 32	54	40	<<
	8	32.6	20 29	54	40	<<
	9	32.7	20 33	58	39	<<
	10	32.8	20 31	55	40	<<
	11	33.0	20 31	55	38	<<
	12	32.8	21 38	55	38	<<
	13	32.4	20 32	56	35	<<
	14	33.0	20 30	57	35	<<
	15	32.7	20 30	60	38	<<
	16	33.0	20 27	60	42	<<
	17	32.8	20 27	60	36	<<
	18	32.1	20 26	60	40	<<
	19	32.6	20 30	55	35	<<
	20	32.6	20 33	55	36	<<
	21	33.0	20 30	54	40	<<
	22	33.0	20 31	54	40	<<
	23	33.0	20 27	55	35	<<
	24	33.0	20 33	54	40	<<
	25	32.7	20 35	60	37	<<
	26	32.7	20 28	60	36	<<
	27	33.0	20 32	54	37	<<
	28	32.6	20 33	55	38	<<
	29	32.6	20 32	55	38	<<
	30	33.0	20 30	60	38	<<
	31	32.4	20 33	55	40	<<
	32	32.7	20 30	55	35	<<
	33	33.0	20 32	55	40	<<
	34	33.0	22 26	60	35	<<
	35	33.0	20 35	57	40	<<
	36	32.5	20 33	60	40	<<
	37	33.0	20 29	60	38	<<
	38	33.0	20 32	60	38	<<
	39	32.9	20 25	56	38	<<
	40	32.7	20 31	60	38	<<
12-14-77	41	32.6	20 32	55	40	<<
	42	33.0	20 31	60	36	<<
	43	33.0	20 31	60	40	<<
	44	33.0	20 32	58	38	<<
	45	33.0	20 32	58	38	<<
	46	33.0	20 30	60	40	<<
	47	33.0	20 33	55	40	<<
	48	32.6	20 28	55	40	<<

PCLN PRESEAL (CONTINUED)

LDC	SN	L_{INS} 30±3	S_{SL} ≥20/25	S_{FT} ≥50	S_{SP} ≥35	VSWR ≤3.5:1
12-14-77	49	33.0	20 32	58	40	<<
	50	33.0	20 32	58	40	<<
	51	33.0	20 32	60	40	<<
	52	33.0	20 32	58	36	<<
	53	33.0	20 33	55	36	<<
	54	32.4	20 33	60	40	<<
	55	33.0	20 33	58	40	<<
	56	33.0	20 30	60	37	<<
	57	33.0	20 28	60	40	<<
	58	33.0	20 31	55	38	<<
	59	33.0	20 30	58	36	<<
	60	33.0	20 33	60	38	<<
	61	33.0	20 32	58	40	<<
	62	32.5	20 28	58	36	<<
	63	32.4	20 32	60	38	<<
	64	33.0	20 30	54	40	<<
	65	33.0	20 30	60	38	<<
	66	32.7	20 33	60	40	<<
	67	33.0	20 30	60	38	<<
	68	32.2	20 32	58	38	<<
	69	32.6	20 31	55	37	<<
	70	33.0	20 30	60	40	<<
	71	33.0	20 28	55	40	<<
	72	32.4	20 33	60	40	<<
	73	33.0	20 32	60	37	<<
	74	33.0	20 33	60	40	<<
	75	33.0	20 30	60	37	<<
	76	33.0	20 31	60	36	<<
	77	33.0	20 30	60	40	<<
	78	32.7	20 33	60	40	<<
	79	33.0	20 26	55	37	<<
	80	33.0	20 28	58	36	<<
	81	33.0	20 31	57	40	<<
	82	33.0	20 30	60	38	<<
	83	33.0	20 28	60	40	<<
	84	32.7	20 33	60	39	<<
	85	32.5	20 32	55	40	<<
	86	32.6	20 31	60	40	<<
	87	32.6	20 33	58	40	<<
	88	32.2	20 32	58	40	<<
	89	31.4	20 33	58	40	<<
	90	32.6	20 33	55	38	<<
12-19-77	91	33.0	20 32	57	38	<<
	92	31.0	20 33	58	37	<<
	93	32.7	20 33	56	38	<<
	94	32.5	20 32	60	36	<<
	95	32.8	20 33	56	38	<<
	96	32.8	20 33	57	40	<<

PCLN PRESEAL (CONTINUED)

LDC	SN	L_{INS} 30±3	S_{SL} ≥20/25	S_{FT} ≥50	S_{SP} ≥35	VSWR ≤3.5:1
12-19-77	97	32.0	20 33	60	37	<<
12-20-77	98	32.9	20 30	60	38	<<
	99	32.7	20 33	60	38	<<
	100	32.8	20 31	60	42	<<
	101	33.0	20 34	57	37	<<
	102	33.0	20 34	60	39	<<
	103	32.6	20 26	60	40	<<
	104	32.0	20 33	60	40	<<
	105	33.0	20 32	60	40	<<
	106	32.0	20 29	60	38	<<
3-14-78	107	32.7	27 29	54	43	<<
	108	32.0	27 29	55	43	<<
	109	32.8	26 29	54	42	<<
	110	32.0	26 29	53	43	<<
	111	31.7	28 28	54	43	<<
	112	32.1	25 29	56	43	<<
	113	32.3	26 30	53	42	<<
	114	31.7	26 28	54	35	<<
	115	32.5	25 30	56	42	<<
	116	31.3	26 30	57	44	<<
	117	31.8	23 28	55	43	<<
	118	29.4	33 29	56	46	<<
	119	33.0	20 28	54	35	<<
	120	32.3	29 28	55	37	<<
	121	32.3	26 29	55	43	<<
	122	31.4	27 29	56	43	<<
	123	31.9	29 27	55	43	<<
	124	32.2	25 28	54	37	<<
	125	32.1	29 27	56	37	<<
	126	32.1	28 28	55	37	<<
	127	32.5	30 27	55	37	<<
3-24-78	128	32.0	26 26	57	41	<<
	129	32.0	26 30	57	35	<<
	130	32.5	33 29	55	40	<<
	131	32.6	29 27	57	37	<<
	132	32.0	34 30	58	38	<<
	133	32.8	32 30	56	43	<<
	134	31.2	30 29	57	40	<<
	135	32.6	27 29	56	36	<<
	136	32.5	27 31	56	36	<<
	137	32.8	32 30	57	39	<<
	138	32.0	29 28	56	37	<<
	139	31.7	32 29	56	38	<<
	140	32.3	32 29	55	37	<<
	141	33.0	33 29	56	42	<<
	142	32.0	31 29	56	37	<<
	143	33.0	29 27	54	35	<<
	144	32.2	32 27	56	38	<<

PCLN PRESEAL (CONTINUED)

LDC	SN	L_{INS} 30±3	S_{SL} ≥20/25	S_{FT} ≥50	S_{SP} ≥35	VSWR ≤3.5:1
3-24-78	145	31.5	33 27	56	40	<<
	146	32.1	32 30	53	39	<<
	147	32.6	28 40	54	37	<<
	148	31.8	28 27	56	40	<<
	149	31.9	34 28	55	39	<<
	150	32.0	25 28	55	36	<<
	151	32.5	27 27	55	39	<<
	152	32.2	27 27	55	37	<<
	153	31.6	27 28	56	39	<<
	154	32.7	28 26	52	36	<<
	155	32.6	27 28	52	36	<<
	156	31.8	29 27	55	35	<<
	157	31.6	25 28	54	38	<<
	158	31.8	28 27	55	37	<<
	159	32.2	28 28	54	38	<<
	160	32.8	30 26	52	35	<<
	161	31.5	23 27	56	38	<<
	162	31.5	28 27	54	38	<<
	163	32.7	33 27	53	40	<<
	164	31.4	26 26	54	39	<<
	165	32.0	25 28	55	36	<<
5-17-78	166	32.0	25 31	53	40	<<
	167	32.7	28 28	52	43	<<
	168	32.4	27 29	54	44	<<
	169	32.0	27 29	56	40	<<
	170	32.2	32 29	55	43	<<
	171	31.8	27 29	55	44	<<
	172	31.9	25 28	54	40	<<
	173	31.8	28 28	55	41	<<
	174	32.1	28 28	55	43	<<
	175	31.7	28 29	55	44	<<
	176	32.2	27 27	54	43	<<
	177	31.8	27 29	55	44	<<
	178	31.7	27 29	54	44	<<
	179	32.7	25 30	55	43	<<
	180	32.3	26 26	56	37	<<
	181	32.8	26 27	58	38	<<
	182	31.6	28 27	57	38	<<

APPENDIX XXI
PHASE IV FINAL ELECTRICAL DATA FOR
PCLN DEVICES

144	45.3	30	58	47	<<

HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

PCLN FINAL DATA

LDC	SN	L_{INS} 27-33	>20/25 S_{SL}	≥50 S_{FT}	>35 S_{SP}	<35:1 VSWR
3-24-78	1	33.0	22 35	55	40	<<
	2	33.0	21 35	56	40	<<
	3	33.0	20 30	55	40	<<
	4	33.0	22 31	55	40	<<
	5	32.6	21 34	56	41	<<
	6	32.9	22 33	55	40	<<
	7	32.4	21 34	54	40	<<
	9	32.7	21 34	55	40	<<
	10	32.9	20 31	56	40	<<
	11	32.9	21 34	50	40	<<
	12	33.0	23 29	55	40	<<
	13	32.5	21 29	56	40	<<
	14	32.4	21 32	56	36	<<
	15	32.7	23 29	56	40	<<
	16	33.0	23 27	56	40	<<
	17	32.7	20 27	57	40	<<
	18	32.1	22 25	57	40	<<
	19	32.7	21 30	56	35	<<
	20	32.6	21 34	56	40	<<
	22	33.0	21 33	56	40	<<
	23	33.0	20 28	56	41	<<
	24	33.0	21 33	56	40	<<
	25	32.5	21 35	57	39	<<
	27	32.8	21 32	56	36	<<
	28	32.5	21 35	56	40	<<
	29	32.5	21 32	55	36	<<
	31	32.3	21 32	56	38	<<
	32	32.3	21 31	56	30	<<
	33	32.8	22 31	56	37	<<
	34	32.8	23 25	56	40	<<
	35	32.9	22 33	56	42	<<
	36	32.3	21 32	54	42	<<
	37	← one port shorted →				
	38	32.8	21 32	56	41	<<
	39	33.0	22 27	55	42	<<
3-27-78	40	32.8	20 32	56	40	<<
	41	32.4	20 34	56	40	<<
	42	33.0	20 33	55	43	<<
	43	33.0	20 32	55	41	<<
	44	32.9	20 35	55	41	<<
	45	33.0	21 33	55	41	<<
	46	33.0	20 31	55	40	<<
	47	33.0	20 33	55	41	<<
	48	32.7	21 29	55	40	<<
	49	32.9	21 35	55	41	<<
	50	32.5	21 32	55	41	<<

192	47.2	30	55	46	<<

PCLN FINAL DATA (Continued)

LDC	SN	L_{INS} 27-33	>20/25 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	<35:1 VSWR
3-27-78	51	33.0	21 34	55	41	<<
	52	32.4	21 32	55	41	<<
	53	32.9	21 31	55	41	<<
	54	32.2	21 34	55	41	<<
	56	32.9	20 32	56	41	<<
	57	32.9	20 29	56	40	<<
	58	33.0	21 33	55	41	<<
	59	32.7	21 31	55	41	<<
	60	32.8	20 30	55	41	<<
	61	32.3	20 30	56	41	<<
	64	32.7	20 31	54	41	<<
	65	32.3	20 30	56	41	<<
	66	32.4	20 30	56	41	<<
	67	32.5	20 31	55	40	<<
	68	32.1	20 31	55	41	<<
	69	32.5	20 28	56	41	<<
	70	32.8	20 32	56	41	<<
	71	32.2	20 28	56	42	<<
	72	32.2	21 33	56	41	<<
	73	33.0	21 34	55	41	<<
	74	34.0	22 33	56	41	<<
	75	32.9	21 30	55	40	<<
3-28-78	76	32.9	21 32	55	41	<<
	77	32.9	22 31	55	42	<<
5-16-78	118					OUT
	119	32.5	20 25	54	42	<<
	120	32.2	30 28	55	43	<<
	121	32.3	28 29	54	43	<<
	122	31.6	28 29	56	44	<<
	123	31.8	31 28	55	43	<<
	124	32.0	25 27	54	42	<<
	125	32.0	30 29	54	43	<<
	126	32.4	28 29	54	42	<<
	127	32.5	32 28	54	43	<<
	128	32.0	26 25	56	43	<<
	129	32.0	26 30	55	42	<<
	130	33.5				
	131	32.5	28 29	56	43	<<
	132	32.1	29 30	56	43	<<
	133	32.7	27 29	55	43	<<
	134	31.0	31 27	56	44	<<
	135	32.4	28 29	56	43	<<
	136	32.4	27 30	55	42	<<
	137	32.6	26 29	55	43	<<
	138	32.4	30 28	54	43	<<
	139	31.5	31 29	56	44	<<

PCLN FINAL DATA (Continued)

LDC	SN	L_{INS} 27-33	>20/25 S_{SL}	>50 S_{FT}	>35 S_{SP}	<35:1 VSWR
5-16-78	140	32.0	34 28	54	43	<<
	141	32.6	27 27	54	43	<<
	143	32.8	27 27	54	42	<<
	144	32.0	33 27	55	44	<<
	145	31.4	29 29	55	44	<<
	146	31.8	30 29	55	44	<<
	147	32.4	29 29	54	42	<<
	148	31.7	29 28	54	45	<<
	149	31.7	27 28	56	44	<<
	150	31.7	28 29	55	44	<<
	151	32.2	28 30	55	44	<<
	152	32.0	28 28	55	44	<<
3-28-78	78	32.6	21 36	55	43	<<
	80	32.9	21 30	56	45	<<
	81	32.9	22 35	55	42	<<
	82	32.6	21 28	56	43	<<
	83	32.8	22 28	56	42	<<
	84	32.4	22 35	56	40	<<
	85	32.4	22 33	55	42	<<
	86	32.5	23 32	56	42	<<
	87	32.4	23 34	55	38	<<
	88	31.9	23 34	55	40	<<
	89	31.3	22 33	56	38	<<
	90	32.5	23 33	56	36	<<
	91	32.7	22 33	55	42	<<
	92	30.9	22 33	58	40	<<
	94	32.4	23 32	57	43	<<
	95	33.0	22 33	56	42	<<
	96	32.7	22 34	56	42	<<
	97	31.9	22 33	58	42	<<
	98	32.8	23 31	57	42	<<
	99	32.6	23 32	56	44	<<
	100	32.6	22 33	57	42	<<
5-16-78	55	33	28 28	54	42	<<
	107	32.5	28 28	54	43	<<
	108	32.1	25 25	54	40	<<
	109	32.8	26 26	53	38	<<
	110	32.2	26 26	54	40	<<
	111	31.7	28 29	54	40	<<
	112	33.0	26 29	54	39	<<
	113	32.2	27 30	54	42	<<
	114	31.8	27 29	53	35	<<
	115	32.4	27 29	53	43	<<
	116	31.4	28 30	56	44	<<
	117	31.8	27 28	55	43	<<
5-16-78	153	31.8	28 30	55	44	<<

PCLN FINAL DATA (Continued)

LDC	SN	L_{INS} 27-33	≥20/25 S_{SL}	≥50 S_{FT}	>35 S_{SP}	≤35:1 VSWR
5-16-78	154	32.5	30 29	50	43	<<
(Cont)	155	32.4	27 29	52	43	<<
	156	31.8	30 26	55	44	<<
	157	31.6	25 28	55	44	<<
	158	31.9	29 30	55	44	<<
	159	32.2	27 29	54	44	<<
	160	32.6	30 29	52	42	<<
5-17 78	161	31.4	22 25	56	44	<<
	162	31.6	29 29	56	45	<<
	163	32.9	27 27	53	43	<<
	164	31.4	27 28	55	44	<<
	165	34.4				
7-25-78	123	32.0	30 27	53	40	<<
	63	32.4	28 26	57	38	<<
	21	32.8	31 26	56	38	<<
	30-8	32.5	40 31	60	38	<<
	142	32.0	21 26	55	37	<<
	93	32.6	28 27	57	40	<<
	167	31.6	23 28	60	36	<<
	174	31.8	25 27	60	41	<<
	178	31.8	25 28	60	39	<<
	180	32.3	26 26	56	37	<<
	181	32.8	26 27	58	38	<<
	182	31.6	28 27	57	38	<<

APPENDIX XXII
PHASE IV PRESEAL ELECTRICAL DATA FOR TDL-100 DEVICES

TDL-100 PRESEAL

LDC	SN	98-102 f_o	24-30 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	4.0:1 VSWR
11-9-77	1	100.08	30	20	50	40	<<
	2	100.09	30	19	50	37	<<
	3	100.10	30	17	50	36	<<
	4	100.08	29	21	50	38	<<
	5	100.09	29	20	50	37	<<
	6	100.09	28	20	50	37	<<
	7	100.09	28	21	50	38	<<
	8	100.09	28	20	50	38	<<
	9	100.08	29	21	50	37	<<
	10	100.08	29	21	50	37	<<
	11	100.08	29	20	50	37	<<
	12	100.08	29	20	50	36	<<
	13	100.08	29	20	50	36	<<
	14	100.08	30	20	50	37	<<
	15	100.09	28	20	50	37	<<
	16	100.09	28	20	50	37	<<
	17	100.08	30	19	50	36	<<
	18	100.09	29	19	50	36	<<
	19	100.08	30	20	50	36	<<
	20	100.09	29	19	50	36	<<
	21	100.10	28	17	50	35	<<
	22	100.08	30	20	50	36	<<
	23	100.10	30	17	50	36	<<
11-10-77	24	100.09	28	18	50	37	<<
	25	100.09	30	18	50	36	<<
	26	100.09	30	19	50	37	<<
	27	100.08	30	19	50	37	<<
	28	100.10	30	19	50	38	<<
	29	100.10	30	17	50	36	<<
	30	100.10	30	17	50	35	<<
	31	100.10	30	17	50	35	<<
	32	100.09	29	20	50	35	<<
	33	100.09	30	19	50	36	<<
	34	100.10	30	18	50	36	<<
	35	100.08	30	19	50	36	<<
11-11-77	36	100.08	30	20	50	36	<<
	37	100.08	30	19	50	38	<<
	38	100.08	30	19	50	37	<<
	39	100.09	30	19	50	36	<<
	40	100.09	30	19	50	37	<<
	41	100.08	28	20	50	38	<<
	42	100.08	28	20	50	36	<<
	43	100.08	28	20	50	36	<<
	44	100.09	29	19	50	36	<<
	45	100.08	30	19	50	37	<<
	46	100.08	30	20	50	36	<<
	47	100.08	30	20	50	36	<<

TDL-100 PRESEAL (Continued)

LDC	SN	98-102 f_o	24-30 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	4.0:1 VSWR
11-11-77 (Cont)	48	100.08	30	20	50	36	<<
	49	100.08	28	20	50	36	<<
	50	100.08	28	20	50	36	<<
	51	100.08	30	20	50	36	<<
	52	100.07	30	20	50	36	<<
	53	100.08	30	19	50	36	<<
	54	100.08	30	20	50	36	<<
	55	100.08	30	19	50	35	<<
	56	100.09	29	19	50	37	<<
	57	100.08	29	19	50	36	<<
11-14-77	58	100.09	30	19	50	36	<<
	59	100.08	30	18	50	40	<<
	60	100.09	27	19	50	39	<<
	61	100.08	29	19	50	37	<<
	62	100.07	30	19	50	36	<<
	63	100.10	30	19	50	35	<<
	64	100.08	29	19	50	37	<<
	65	100.08	28	20	50	37	<<
	66	100.08	30	19	50	36	<<
	67	100.08	30	19	50	36	<<
	68	100.09	30	19	50	36	<<
	69	100.08	28	20	50	37	<<
	70	100.08	30	19	50	37	<<
	71	100.08	29	19	50	37	<<
	72	100.08	30	19	50	36	<<
	73	100.08	28	20	50	37	<<
	74	100.08	28	19	50	37	<<
	75	100.08	28	20	50	37	<<
	76	100.09	30	19	50	36	<<
11-15-77	77	100.10	30	20	50	35	<<
	78	100.11	30	20	50	39	<<
	79	100.10	30	20	50	36	<<
	80	100.09	30	19	50	36	<<
	81	100.10	29	20	50	35	<<
	82	100.10	29	20	50	36	<<
	83	100.13	30	20	50	38	<<
	84	100.11	30	19	50	36	<<
	85	100.11	28	20	50	36	<<
	86	100.10	30	20	50	37	<<
	87	100.10	28	19	50	37	<<
	88	100.10	30	20	50	37	<<
	89	100.13	30	19	50	40	<<
	90	100.13	30	20	50	38	<<
	91	100.13	30	20	50	38	<<
	92	100.10	29	19	50	37	<<
	93	100.09	30	19	50	35	<<
	94	100.08	30	18	50	35	<<

TDL-100 PRESEAL (Continued)

LDC	SN	98-102 f_o	24-30 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	4.0:1 VSWR
	95	100.09	30	19	50	36	<<
	96	100.09	30	19	50	35	<<
	97	100.09	30	19	50	35	<<
	98	100.06	30	19	50	36	<<
	99	100.08	30	19	50	37	<<
	100	100.10	30	18	50	37	<<
	101	100.09	30	19	50	39	<<
1-4-78	102	100.10	30	18	54	38	<<
	103	100.10	30	18	51	37	<<
	104	100.11	30	18	56	36	<<
	105	100.09	38	18	58	36	<<
1-4-77	106	100.10	30	18	57	37	<<
	107	100.11	30	18	58	36	<<
	108	100.11	31	17	56	36	<<
	109	100.10	31	18	50	36	<<
	110	100.10	31	17	54	35	<<
	111	100.95	29	19	55	37	<<
	112	100.84	29	18	54	37	<<
	113	100.96	30	18	54	38	<<
	114	100.97	30	18	53	35	<<
2-2-78	115	100.09	30	19	55	37	<<
	116	100.09	29	19	52	38	<<
	117	100.09	30	19	55	36	<<
	118	100.10	30	18	50	37	<<
	119	100.10	29	19	50	37	<<
	120	100.09	30	19	54	36	<<
	121	100.09	30	18	51	36	<<
	122	100.09	30	18	51	36	<<
	123	100.10	30	18	55	38	<<
	124	100.09	30	18	55	39	<<
2-6-78	125	100.11	30	18	55	37	<<
	126	100.11	30	18	57	39	<<
	127	100.11	30	18	57	38	<<
	128	100.11	30	17	57	38	<<
	129	100.11	30	18	57	38	<<
	130	100.11	30	18	57	36	<<
	131	100.11	30	18	53	35	<<
	132	100.11	30	18	53	35	<<
3-20-78	133	100.09	28	19	50	38	<<
	134	100.10	30	19	50	36	<<
	135	100.10	29	17	50	38	<<
	136	100.10	28	19	50	37	<<
	137	100.11	30	17	50	37	<<
3-21-78	138	100.08	30	20	50	38	<<
	139	100.08	29	18	50	40	<<
8-27-78	140	100.08	28	20	52	37	<<
	141	100.08	28	19	51	36	<<

TDL-100 PRESEAL (Continued)

LDC	SN	98-102 f_o	24-30 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	4.0:1 VSWR
8-27-78	142	100.09	30	19	51	38	<<
(Cont)	143	100.08	28	20	52	37	<<
	144	100.08	27	20	52	38	<<
	145	100.09	28	19	51	37	<<
8-28-78	146	100.08	28	20	52	38	<<
	147	100.08	29	18	52	39	<<
	148	100.08	26	19	53	36	<<
	149	100.07	28	20	52	36	<<
	150	100.08	28	19	52	36	<<
	151	100.09	29	20	52	36	<<
	152	100.11	28	19	52	38	<<
	153	100.08	28	20	52	36	<<
	154	100.09	28	18	50	39	<<
	155	100.08	30	17	50	35	<<
	156	100.10	27	19	50	38	<<
	157	100.10	26	19	53	38	<<
	158	100.10	26	20	53	37	<<
	159	100.07	27	18	53	35	<<
	160	100.07	26	20	53	36	<<
	161	100.07	27	18	53	35	<<
	162	100.08	27	19	52	35	<<
	163	100.08	27	19	52	35	<<
	164	100.08	27	18	52	35	<<
	165	100.08	29	18	50	35	<<
	166	100.09	28	20	52	36	<<
	167	100.06	30	19	50	35	<<
	168	100.08	30	19	50	35	<<
	169	100.09	29	20	51	38	<<
	170	100.09	29	20	53	36	<<
	171	100.08	29	18	50	36	<<
	172	100.08	29	19	51	35	<<
	173	100.08	28	20	53	37	<<
	174	100.08	28	19	51	36	<<
	175	100.08	29	19	52	36	<<
	176	100.08	30	19	50	35	<<
	177	100.08	27	20	53	35	<<
5-18-78	178		28	20	52	35	<<
	179		29	18	52	36	<<
	180		29	20	53	37	<<
	181		29	20	53	36	<<
	182		28	20	54	37	<<
	183		28	20	54	38	<<
	184		28	19	53	37	<<
	185		29	18	52	36	<<
	186		28	20	53	37	<<
	187		28	19	53	36	<<
	188		28	20	52	40	<<

TDL-100 PRESEAL (Continued)

LDC	SN	98-102 f_o	24-30 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	4.0:1 VSWR	
5-18-78								
(Cont)	189		28	20	53	37	<<	
	190		28	20	52	36	<<	
	191		28	19	52	37	<<	
5-31-78	192		28	20	50	38	<<	
	193 -	203 Phase 3 Overage						

APPENDIX XXIII
PHASE IV FINAL ELECTRICAL DATA FOR TDL-100 DEVICES

TDL-100 FINAL TEST

LDC	SN	f_O 98-102	L_{ins} 24-30	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 4:1
3-27-78	2	100.10	28	20	52	36	<<
	3	100.11	28	17	52	37	<<
	7	100.09	27	20	53	38	<<
	17						IN
	20	100.09	28	20	52	38	<<
	21	100.11	27	18	53	37	<<
	25	100.09	28	19	51	37	<<
	34	100.09	28	17	50	38	<<
	51	100.08	29	19	52	37	<<
	60	100.08	27	20	53	38	<<
	66	100.08	29	19	53	40	<<
	84	100.10	27	20	53	40	<<
	87	100.10	27	18	52	40	<<
	90	100.13	30	17	51	38	<<
	105	100.09	26	20	53	36	<<
	112						OUT
	113	← solder balls →					
	127	100.10	27	19	52	39	<<
	128						IN
	133	100.10	26	19	52	37	<<
	134						IN
	136						IN
	139	100.07	28	18	51	37	<<
3-29-78	26	100.09	29	20	50	41	<<
	27	100.09	29	20	50	41	<<
	28						IN
	29	100.11	30	17	50	37	<<
	32	100.09	29	20	50	36	<<
	33	100.09	28	19	50	42	<<
	35	100.08	29	20	50	40	<<
	37	100.08	29	19	50	40	<<
	38	100.09	29	20	50	40	<<
	39	100.09	29	19	50	41	<<
	40	100.08	27	20	50	39	<<
	41	100.08	27	20	50	39	<<
	42	100.08	28	20	50	39	<<
	43	100.09	27	20	50	39	<<
	45	100.09	29	20	50	42	<<
	48						IN
	49	100.08	28	20	50	38	<<
	53	100.08	29	20	50	41	<<
	54	100.08	30	20	50	40	<<
	57	100.08	29	20	50	41	<<
	58	100.09	29	19	50	40	<<
	59	100.09	30	19	50	42	<<

TDL-100 FINAL TEST (Continued)

LDC	SN	f_o 98-102	L_{ins} 24-30	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 4:1
3-29-78	61	100.09	29	20	50	41	<<
	62	100.08	29	20	50	40	<<
	63						IN
	64	100.08	28	20	50	40	<<
	65	100.08	27	20	50	38	<<
	67	100.08	30	19	50	40	<<
	68	100.10	30	19	50	40	<<
	70	100.09	30	20	50	40	<<
	74						IN
	76						OUT
	77	100.11	29	20	50	40	<<
	78						IN/OUT
	79	100.10	30	17	50	39	<<
3-29-78	80	100.10	30	18	50	40	<<
	81	100.11	28	19	50	37	<<
3-30-78	82	100.11	29	20	50	48	<<
	83	100.13	29	18	50	48	<<
	86						OUT
	88	100.11	27	20	50	39	<<
	91	100.13	29	19	50	38	<<
	92	100.11	28	19	50	36	<<
	93	100.09	29	19	50	36	<<
	94						IN
	95	100.09	29	20	50	40	<<
	96	100.09	30	19	50	38	<<
	102	100.09	27	19	50	37	<<
	103						OUT
	106						IN
	107						IN
	108	100.11	28	19	50	35	<<
	110	100.11	27	20	50	35	<<
	111	100.08	26	19	50	35	<<
	115	100.09	26	20	50	35	<<
	117	100.08	27	20	50	35	<<
	118	100.09	26	19	50	36	<<
	119	100.09	26	20	50	37	<<
4-8-78	1	100.10	29	20	52	37	<<
	4	100.11	28	20	52	36	<<
	6	100.09	28	20	53	37	<<
	8						IN
	12	100.09	28	20	54	36	<<
	13	100.11	28	20	53	37	<<
	14						IN/OUT
	121	100.09	27	20	53	37	<<
	124	100.09	28	19	53	37	<<
	153	100.09	29	17	51	37	<<

TDL-100 FINAL TEST (Continued)

LDC	SN	f_o 98-102	L_{ins} 24-30	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 4:1
4-8-78	30	100.11	27	20	51	42	<<
	76	100.11	27	20	51	38	<<
	99	100.09	29	18	50	39	<<
	103	100.09	25	19	53	36	<<
	124						IN/OUT
	126						IN/OUT
	129						IN/OUT
	131						IN/OUT
	133						IN/OUT
	137						IN/OUT
	138						OUT
	139						IN/OUT
5-30-78	8	100.08	28	18	50	37	<<
	9	100.08	28	20	52	36	<<
	16	100.08	27	19	53	37	<<
	22	100.08	30	20	50	37	<<
	23	100.09	28	20	52	37	<<
	31	100.09	29	20	51	36	<<
	47		43				
	63	100.10	30	20	50	37	<<
	69	100.09	29	20	51	36	<<
	74	100.09	27	19	50	35	<<
	85	100.10	30	19	50	40	<<
	86	100.11	28	19	50	40	<<
	89		32				
	104	100.08	28	20	53	37	<<
	109	100.08	27	20	53	37	<<
	120	100.08	28	20	53	36	<<
	123	100.10	27	20	53	38	<<
	125	100.10	27	20	52	38	<<
	130	100.10	28	20	53	40	<<
	140	100.08	28	20	52	37	<<
	143	100.08	29	19	52	36	<<
	145	100.09	27	20	53	37	<<
	149	100.08	28	20	52	36	<<
	150						IN
	151	100.09	30	20	50	40	<<
	154						IN
	161	100.07	29	19	50	36	<<
	162	100.07	28	19	52	35	<<
	166	100.09	27	20	52	37	<<
	167		30	18	50	33	<<
	168	100.08	30	19	50	38	<<
	169	100.09	29	20	50	39	<<
	170	100.07	28	20	51	39	<<
	171	100.07	29	20	51	35	<<
	172	100.07	29	19	50	35	<<

TDL-100 FINAL TEST (Continued)

LDC	SN	f_o 98-102	L_{ins} 24-30	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 4:1
5-30-78	126						IN
	156	100.08	28	19	51	38	<<
	193	100.08	26	18	53	36	<<
	194	100.08	26	19	53	36	<<
	195	100.08	26	19	53	36	<<
	196	100.08	26	20	53	36	<<
	197	100.08	25	19	53	37	<<
	198	100.08	16	20	53	36	<<
	199	100.09	26	20	52	36	<<
	200	100.07	25	18	54	35	<<
	201	100.08	27	20	53	37	<<
	202	100.10	28	19	53	37	<<
	204	100.10	38	18	53	36	<<
	205	100.10	28	18	51	37	<<
	206	100.08	28	18	52	36	<<
	207	100.08	27	18	53	37	<<
	208	100.08	25	19	54	35	<<
	209	100.09	28	18	51	39	<<
	210	100.09	28	18	51	36	<<
	211	100.09	28	18	51	37	<<
	203	100.08	25	19	54	35	<<
6-8-78	18	100.09	28	19	52	37	<<
	19	100.08	30	20	50	35	<<
	52	100.08	30	20	52	37	<<
	55	100.08	30	19	53	39	<<
	71	100.08	28	20	52	40	<<
	72	100.08	30	19	52	40	<<
	78	100.10	29	19	53	40	<<
	106	100.10	26	19	52	39	<<
	116	100.08	27	20	53	38	<<
	141	100.08	28	19	51	37	<<
	142						IN
	144	100.08	27	19	53	37	<<
	146	100.08	28	20	53	39	<<
	147	100.10	29	20	52	41	<<
	152	100.13	30	18	52	40	<<
	153	100.08	30	20	52	39	<<
	155	100.08	30	19	52	35	<<
	157	100.11	28	20	53	39	<<
	158	100.09	28	20	54	40	<<
	163	100.08	28	19	53	39	<<
	165	100.08	28	20	53	35	<<
	173	100.09	27	20	54	38	<<
	177	100.09	27	19	53	38	<<
2-26-78	159	100.07	29	18	50	35	<<
	184						IN
	190	100.08	29	18	51	40	<<

APPENDIX XXIV
PHASE IV PRESEAL ELECTRICAL DATA FOR TDL-200 DEVICES

TDL 200 PRECAP

LDC	SN	f_o 198-202	LINS 23-29	SSL >17	SFT >50	SSP >35	VSWR 3:1
2-17-78	1	200.13	29	17	55	41	✓✓
	2	200.13	29	18	55	43	✓✓
	3	200.13	28	18	56	41	✓✓
	4	200.10	28	17	56	40	✓✓
	5	200.14	29	17	56	41	✓✓
2-21-78	6	200.13	29	17	50	42	✓✓
	7	200.13	29	18	51	41	✓✓
	8	200.14	29	18	51	40	✓✓
	9	200.16	28	17	52	40	✓✓
	10	200.13	28	19	53	41	✓✓
	11	200.15	28	17	54	40	✓✓
	12	200.15	28	18	53	42	✓✓
	13	200.14	28	19	52	42	✓✓
	14	200.16	28	18	53	42	✓✓
	15	200.16	28	17	54	41	✓✓
	16	200.15	27	17	54	41	✓✓
	17	200.15	28	18	54	41	✓✓
	18	200.16	28	17	54	42	✓✓
	19	200.12	27	18	54	38	✓✓
	20	200.15	29	17	52	41	✓✓
	21	200.17	29	18	53	40	✓✓
	22	200.15	29	17	53	41	✓✓
	23	200.12	28	18	53	40	✓✓
	24	200.16	28	18	54	40	✓✓
	25	200.13	28	17	55	37	✓✓
	26	200.16	29	17	54	41	✓✓
	27	200.16	28	17	55	40	✓✓
	28	200.13	27	18	55	39	✓✓
	29	200.13	27	18	55	40	✓✓
	30	200.13	28	18	55	38	✓✓
	31	200.16	28	17	50	40	✓✓
	32	200.13	28	18	54	40	✓✓
	33	200.13	28	18	55	40	✓✓
	34	200.11	28	17	55	38	✓✓
	35	200.16	29	17	55	41	✓✓
	36	200.13	27	18	50	38	✓✓
	37	200.12	27	17	50	35	✓✓
	38	200.13	27	18	50	38	✓✓
	39	200.14	27	18	53	41	✓✓
	40	200.11	28	18	50	37	✓✓
	41	200.14	27	18	50	41	✓✓
	42	200.14	27	18	50	40	✓✓
	43	200.12	27	18	50	37	✓✓
	44	200.14	28	17	50	42	✓✓
	45	200.15	27	17	50	42	✓✓
	46	200.15	28	17	53	42	✓✓
	47	200.15	29	18	53	42	✓✓
	48	200.12	28	17	53	35	✓✓

TDL 200 PRECAP (CONTINUED)

LDC	SN	f_O 198-202	LINS 23-29	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 3:1
2-21-78	49	200.12	27	18	53	38	<<
	50	200.13	27	18	53	39	<<
	51	200.12	26	18	50	39	<<
	52	200.16	28	17	55	42	<<
	53	200.12	28	17	53	37	<<
	54	200.13	26	18	53	39	<<
	55	200.14	28	17	53	42	<<
	56	200.12	28	18	53	39	<<
	57	200.12	28	18	53	40	<<
3-17-78	58	200.14	29	18	55	41	<<
	59	200.14	28	18	55	40	<<
	60	200.14	29	18	50	43	<<
	61	200.14	29	18	55	40	<<
	62	200.14	28	18	55	39	<<
	63	200.14	28	18	55	37	<<
	64	200.13	28	18	55	38	<<
	65	200.13	28	18	55	38	<<
	66	200.12	29	19	55	39	<<
	67	200.12	27	18	55	39	<<
	68	200.10	28	17	55	37	<<
	69	200.13	28	18	55	39	<<
	70	200.12	28	17	55	35	<<
	71	200.14	25	20	50	40	<<
	72	200.14	29	17	55	39	<<
	73	200.13	25	19	50	39	<<
	74	200.12	24	21	55	37	<<
3-18-78	75	200.12	25	17	50	35	<<
	76	200.15	25	18	50	38	<<
	77	200.13	24	20	50	37	<<
	78	200.12	25	17	50	36	<<
	79	200.12	25	19	50	36	<<
	80	200.12	26	17	50	35	<<
	81	200.12	26	20	50	35	<<
	82	200.12	26	20	50	35	<<
	83	200.12	25	20	50	35	<<
	84	200.13	25	20	50	40	<<
	85	200.16	27	20	50	40	<<
	86	200.16	26	18	50	39	<<
	87	200.16	27	17	50	37	<<
	88	200.13	25	21	50	40	<<
	89	200.13	26	20	50	40	<<
	90	200.15	26	19	50	39	<<
	91	200.16	25	18	50	38	<<
	92	200.15	25	20	50	38	<<
	93	200.16	25	18	50	40	<<
	94	200.14	26	20	50	39	<<
	95	200.14	26	20	50	40	<<
	96	200.13	29	19	50	42	<<

TDL 200 PRECAP (CONTINUED)

LDC	SN	f_O 198-202	LINS 23-29	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 3:1
3-18-78	97	200.15	25	19	50	40	<<
	98	200.15	25	20	50	40	<<
	99	200.15	25	20	50	40	<<
	100	200.15	24	18	50	35	<<
	101	200.15	25	17	50	40	<<
	102	200.15	24	20	50	40	<<
	103	200.15	25	20	50	40	<<
	104	200.16	25	18	50	40	<<
	105	200.15	25	19	50	37	<<
	106	200.12	25	18	50	38	<<
	107	200.12	25	17	50	38	<<
	108	200.13	28	20	50	38	<<
	109	200.14	25	20	50	38	<<
	110	200.12	25	20	50	35	<<
	111	200.14	24	19	50	36	<<
	112	200.14	25	20	50	35	<<
	113	200.14	24	20	50	37	<<
	114	200.14	24	20	50	38	<<
3-19-78	115	200.16	28	18	50	35	<<
	116	200.14	29	17	56	41	<<
4-26-78	117	200.12	26	17	52	38	<<
	118	200.11	29	19	50	38	<<
	119	200.12	24	20	55	40	<<
	120	200.11	24	20	55	38	<<
	121	200.13	24	20	55	38	<<
	122	200.13	24	19	55	38	<<
	123	200.13	25	20	55	37	<<
	124	200.13	25	20	55	37	<<
	125	200.13	25	20	54	37	<<
	126	200.13	25	20	54	38	<<
	127	200.13	25	20	53	38	<<
	128	200.12	24	20	55	37	<<
	129	200.12	25	18	54	37	<<
	130	200.10	27	17	52	37	<<
	131	200.12	26	19	52	38	<<
	132	200.12	24	21	54	37	<<
	133	200.12	24	20	53	38	<<
	134	200.11	25	18	53	38	<<
	135	200.12	25	20	54	39	<<
	136	200.12	25	20	53	38	<<
	137	200.11	26	17	52	39	<<
	138	200.12	25	20	53	40	<<
	139	200.12	24	20	53	40	<<
	140	200.12	25	20	55	39	<<
	141	200.12	24	20	55	40	<<
	142	200.12	24	19	53	38	<<
	143	200.12	25	19	53	39	<<

TDL 200 PRECAP (CONTINUED)

LDC	SN	f_o 198-202	LINS 23-29	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 3:1
4-26-78	144	200.11	26	19	53	39	<<
	145	200.11	25	18	53	38	<<
	146	200.13	25	20	54	40	<<
	147	200.13	24	20	54	40	<<
	148	200.13	25	19	55	40	<<
	149	200.12	26	20	55	40	<<
	150	200.12	26	20	55	39	<<
	151	200.15	24	18	56	40	<<
	152	200.12	24	20	54	40	<<
	153	200.14	26	19	54	40	<<
	154	200.11	25	20	54	38	<<
	155	200.14	26	20	53	40	<<
4-27-78	156	200.16	26	17	54	40	<<
	157	200.16	26	17	53	40	<<
	158	200.16	26	20	55	39	<<
	159	200.09	25	19	50	40	<<
	160	200.15	26	18	54	40	<<
	161	200.15	26	19	54	40	<<
	162	200.15	25	20	54	38	<<
	163	200.09	25	19	55	40	<<
	164	200.15	26	18	52	43	<<
	165	200.17	27	19	52	41	<<
	166	200.17	28	20	50	37	<<
	167	200.17	27	19	52	41	<<
	168	200.17	27	17	50	36	<<
	169	200.16	27	19	52	40	<<
5-19-78	170	200.14	25	20	55	36	<<
	171	200.14	26	19	55	39	<<
	172	200.12	25	20	55	35	<<
	173	200.12	25	18	54	36	<<
	174	200.14	26	20	54	35	<<
	175	200.14	26	20	54	35	<<
	176	200.13	26	20	53	35	<<
	177	200.13	25	20	54	36	<<
	178	200.13	25	20	53	36	<<
	179	200.13	25	19	50	35	<<
	180	200.14	26	19	50	40	<<
	181	200.14	26	19	50	35	<<
5-31-78	182	200.13	29	20	55	38	<<
	183	200.13	28	18	55	36	<<
	184	200.13	24	18	55	38	<<
	185	200.15	27	18	58	38	<<
	186	200.15	24	18	56	40	<<
	187	200.17	25	19	54	38	<<
	188	200.13	25	19	55	39	<<
	189	200.13	24	20	56	28	<<
	190	200.17	25	18	55	40	<<

TDL 200 PRECAP (CONTINUED)

	SN	f_o 198-202	LINS 23-29	S_{SL} ≥17	S_{FT} ≥50	S_{SP} ≥35	VSWR 3:1
6-9-78	191		24	19	55	40	<<
	192		24	18	55	40	<<
	193		26	19	55	40	<<
	194		25	19	55	43	<<
	195-201 Phase III Overage						

APPENDIX XXV
PHASE IV FINAL ELECTRICAL DATA FOR TDL-200 DEVICES

TDL-200 FINAL TEST

LDC	SN	198-202 f_o	23-29 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	3:1 VSWR
3-7-78	2						out
	3	200.13	25	18	54	38	<<
	4	200.15	27	17	52	37	<<
3-8-78	7	200.12	28	17	55	37	<<
	25						in
	28	200.12	24	20	58	41	<<
	29	200.12	24	19	57	42	<<
	30						in
	32	200.12	24	21	57	40	<<
	34	200.12	25	19	55	40	<<
	35		29	13	53	40	<<
	36	200.13	25	19	55	41	<<
	37	200.12	25	20	57	42	<<
	39	200.13	27	17	55	40	<<
	42	200.13	26	17	55	42	<<
	44	200.14	26	18	54	44	<<
	45	200.14	27	17	54	41	<<
	47	200.15	27	19	54	43	<<
	49	200.13	25	17	55	39	<<
	51						out
	52	200.16	28	17	53	40	<<
	53	200.12	25	18	55	39	<<
	56	200.12	25	19	55	38	<<
	60	200.13	25	20	56	39	<<
	62	200.14	25	20	55	38	<<
	63	200.12	25	20	55	38	<<
	66	200.11	26	20	53	38	<<
	67	200.11	25	19	55	38	<<
	69	200.12	25	20	55	38	<<
	70	200.11	25	20	56	38	<<
	71	200.12	25	19	55	38	<<
	72						in/out
	74	200.12	24	21	55	38	<<
	75	200.12	25	20	56	40	<<
	76	200.14	25	18	55	37	<<
	78	200.11	25	28	55	37	<<
	79	200.11	25	18	55	39	<<
	80	200.11	25	19	55	38	<<
	83	200.12	25	20	55	40	<<
	84	200.12	25	20	55	40	<<
	87	200.15	26	19	55	39	<<
	88	200.13	25	20	55	40	<<
	89	200.12	25	19	55	39	<<
	90	200.15	25	17	55	38	<<
	91	200.15	25	17	55	38	<<
	93	200.15	25	18	55	38	<<

TDL-200 FINAL TEST (Continued)

LDC	SN	198-202 f_o	23-29 LINS	≥ 17 S_{SL}	≥ 50 S_{FT}	≥ 35 S_{SP}	3:1 VSWR
3-8-78	94	200.13	25	20	55	40	<<
	97	200.14	24	19	55	42	<<
	99						In
	100	200.13	24	19	57	41	<<
	101	200.15	24	19	56	40	<<
	102	200.15	24	19	57	40	<<
	104	200.15	24	19	56	40	<<
	107	200.12	26	20	54	39	<<
	108	200.12	28	20	52	38	<<
	110	200.12	25	21	55	37	<<
	111	200.14	25	20	55	39	<<
	112	200.13	25	20	55	40	<<
	114	200.16	25	19	55	38	<<
4-26-78	10	200.14	26	20	52	40	<<
	21						out
	23	200.12	27	19	51	38	<<
	27	200.17	27	17	50	40	<<
	31	200.17	26	17	52	40	<<
	33	200.13	24	20	54	38	<<
	40						In
	50	200.13	24	19	55	39	<<
	54	200.13	24	20	55	39	<<
	55						In
	58						In
	61	200.13	26	20	53	40	<<
	65	200.13	25	21	53	39	<<
	68						In
	92	200.13	25	21	53	38	<<
	95	200.13	26	20	53	38	<<
	109	200.13	26	17	53	38	<<
	113	200.14	25	20	54	39	<<
	115	200.15	28	19	53	40	<<
5-17-78	1						
	6	200.15	25	20	55	40	<<
	8	200.15	25	20	55	37	<<
	12	200.15	25	20	55	37	<<
	15	200.16	26	19	55	39	<<
	17	200.17	27	18	53	39	<<
	18	200.17	26	20	54	37	<<
	20	200.16	26	19	53	39	<<
	38		36				
	43	200.14	25	20	55	37	<<
	48	200.14	24	20	55	37	<<
	57	200.15	25	29	54	36	<<
	77	200.17	26	20	55	43	<<
	82						In

TDL-200 FINAL TEST (Continued)

LDC	SN	198-202 f_o	23-29 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	3:1 VSWR
5-17-78	118	200.11	28	19	55	41	<<
5-18-78	119						out
	120	200.12	25	20	55	37	<<
	121	200.12	25	20	54	37	<<
	122	200.12	26	19	54	36	<<
	123	200.12	26	20	55	37	<<
	125	200.12	27	19	54	39	<<
	128	200.13	25	20	55	36	<<
	134						out
6-8-78	2	200.17	25	19	55	39	<<
	15	200.17	25	17	54	39	<<
	16	200.17	25	19	54	39	<<
	19	200.17	26	18	53	42	<<
	35	200.17	26	18	54	38	<<
	51	200.15	25	20	55	40	<<
	73	200.17	25	20	55	38	<<
	96	200.16	28	20	54	40	<<
	98	200.16	25	19	56	38	<<
	103	200.16	24	19	55	39	<<
	106						in
	127						out
	130	200.11	28	17	52	39	<<
	138	200.13	25	20	55	38	<<
	143	200.12	26	19	55	39	<<
	145	200.12	26	18	55	39	<<
	148	200.15	25	20	55	40	<<
	152	200.14	23	20	56	42	<<
	153	200.17	27	19	54	40	<<
	154	200.14	26	20	55	40	<<
	155	200.15	27	20	55	40	<<
	158	200.18	26	17	54	40	<<
	160	200.18	25	18	54	40	<<
	163	200.12	25	18	56	40	<<
	164	200.17	25	18	55	40	<<
	165	200.18	27	17	53	40	<<
	166	200.18	29	20	53	43	<<
	167	200.19	27	17	53	40	<<
	168						out
5-18-78	135	200.12	26	19	54	37	<<
	136	200.12	26	19	54	36	<<
	140	200.13	25	18	54	35	<<
	141	200.13	25	19	55	35	<<
	142	200.13	25	18	54	35	<<
	146	200.15	26	19	54	38	<<
	147	200.14	25	20	55	36	<<
	149	200.12	27	20	44	39	<<

TDL-200 FINAL TEST (Continued)

LDC	SN	198-202 f_o	23-29 LINS	≥17 S_{SL}	≥50 S_{FT}	≥35 S_{SP}	<3:1 VSWR
5-18-78	150	200.12	27	20	53	36	<<
	169	200.13	27	20	54	39	<<
5-31-78	14	200.15	26	19	54	41	<<
	30	200.12	29	17	50	41	<<
	26						
	64	200.16	26	18	54	40	<<
	81						
	85	200.15	26	20	54	40	<<
	105	200.16	25	19	55	38	<<
	117	200.12	25	19	55	39	<<
	132	200.13	25	20	55	38	<<
	156			16			
	159						In
	161		34				
	162	200.16	27	18	52	39	<<
7-26-78	22	200.15	26	17	53	39	<<
	131	200.11	26	18	53	38	<<
	180	200.12	25	19	53	39	<<
	195	200.11	24	19	54	38	<<
	196	200.13	25	20	54	40	<<
	197	200.15	26	19	53	41	<<
	198	200.13	24	19	54	40	<<
	199	200.12	27	17	51	37	<<
	200	200.14	29	26	52	38	<<

APPENDIX XXVI
GROUP C ELECTRICAL TEST DATA

1950512-100 – BPQ LIFE – Subgroup II

SN	98-102 fo	1.96-2.04 BW	18-22 Lins	≥35 S_{sl}	≥35 S_{ft}	≥35 S_{sp}	≤2:1 VSWR
69 I	–	–	18.7	–	66	40	No Failures
F	100.20	2.00	18.5	>35	60	41	
P	0	0	-1.1	0	-9.1	+2.5	
130 I	–	1.99	19.0	–	–	40	
F	100.165	1.97	18.7	>35	60	41	
P	0	-1.0	-1.6	0	0	+2.5	
40 I	–	–	18.9	–	62	42	
F	100.225	2.01	18.8	>35	58	43	
P	0	0	-0.5	0	-6.5	+2.4	
100 I	–	2.01	19.0	–	62	–	
F	100.21	2.00	18.8	>35	58	42	
P	0	-0.5	-1.1	0	-6.5	0	
89 I	100.22	–	19.1	–	63	42	
F	100.21	2.00	18.8	>35	61	43	
P	0	0	-1.6	0	-3.2	+2.4	
28 I	100.225	–	18.9	–	60	40	
F	100.235	1.99	18.7	>35	58	42	
P	0	0	-1.1	0	-3.4	+5.0	
Δ_{AVE} (%)	0	-0.3	-1.2	0	-4.8	+2.5	
MOISTURE – Subgroup III and I							
46 I	–	2.01	18.5	–	60	–	No Failures
F	100.22	2.00	18.4	>35	64	42	
P	0	-0.5	-0.5	0	-6.7	0	
35 I	–	1.99	19.3	–	–	–	
F	100.22	2.00	19.1	>35	57	42	
P	0	+0.5	-1.0	0	0	0	
164 I	–	2.00	–	–	64	42	
F	100.215	1.99	19.4	>35	56	43	
P	0	-0.5	0	0	-12.5	+2.4	
99 I	–	2.01	18.7	–	67	–	
F	100.21	2.00	18.5	>35	63	41	
P	0	+0.5	-1.1	0	-6.3	0	
159 I	100.20	–	–	–	65	42	
F	100.19	2.00	19.2	>35	60	41	
P	0	0	0	0	-8.3	-2.4	
153 I	100.19	–	19.5	–	70	–	
F	100.18	2.02	19.4	>35	60	42	
P	0	0	-0.5	0	-16.7	0	
Δ_{AVE} (%)							

NOTES:
1. Dash indicates initial/final values are unchanged.
2. "I" indicates the parameter value at the in-process final electrical test (see Figure 5.1-3).
3. "F" indicates the parameter value after exposure to Group C, Subgroup II or Subgroup I/III testing, as noted.
4. "P" indicates the percentage changes from initial to final readings (F-I/I x 100), rounded to the nearest tenth percent.
5. "Δ_{AVE} (%) indicates the average of all "P" values for the parameter and subgroup noted.

1950515-100 – BPLN LIFE – Group II

SN	147-153 fo	29.4-30.6 BW	18.5-21.5 Lins	≥35 S_{sl}	≥50 S_{ft}	≥35 S_{sp}	≤3:1 VSWR
15 I	–	30.03	19.2	–	57	37	No Failures
F	151.095	30.05	19.0	>35	65	47	
P	0	0	-1.0	0	+14	+27	
65 I	150.915	29.93	19.7	–	62	39	
F	151.00	29.62	19.6	>35	61	44	
P	0	-1.0	-0.5	0	-1.6	+12.8	
84 I	–	29.94	19.5	–	65	37	
F	150.81	29.92	19.8	>35	60	36	
P	0	0	+1.5	0	-7.7	-2.7	
77 I	150.97	29.99	19.0	–	–	–	
F	151.04	30.18	19.3	>35	60	37	
P	0	+0.6	+1.6	0	0	0	
122 I	151.17	29.94	19.8	–	55	37	
F	151.115	29.75	19.7	>35	61	36	
P	0	-0.6	-0.5	0	+10.9	-2.7	
5 I	150.865	–	20.7	–	62	–	
F	150.855	29.93	20.5	>35	60	38	
P	0	0	-1.0	0	-3.2	0	
Δ_{AVE} (%)	0	-0.2	0	0	+2.1	+5.7	
MOISTURE – Group I and III							
126 I	151.11	29.71	–	–	57	36	No Failures
F	151.18	29.64	19.6	>35	60	35	
P	0	-0.2	0	0	+5.3	-2.8	
4 I	–	–	19.4	–	55	37	
F	151.11	29.66	19.5	>35	54	38	
P	0	0	+0.5	0	-1.8	+2.7	
139 I	–	–	20.4	–	69	39	
F	150.90	29.82	20.3	>35	65	38	
P	0	0	-0.5	0	-5.8	-2.6	
114 I	–	29.79	19.3	–	56	37	
F	150.87	29.92	19.4	>35	58	36	
P	0	+0.4	+0.5	0	+3.6	-2.7	
8 I	150.97	29.87	19.3	–	61	–	
F	150.94	29.84	19.1	>35	63	37	
P	0	-0.1	-1.0	0	+3.3	0	
37 I	–	29.76	18.8	–	–	37	
F	150.795	29.85	18.9	>35	55	36	
P	0	+0.3	+0.5	0	0	-2.7	
Δ_{AVE} (%)	0	+0.1	0	0	+0.8	-1.4	

NOTES:
1. Dash indicates initial/final values are unchanged.
2. "I" indicates the parameter value at the in-process final electrical test (see Figure 5.1-3).
3. "F" indicates the parameter value after exposure to Group C, Subgroup II or Subgroup I/III testing, as noted.
4. "P" indicates the percentage changes from initial to final readings (F-I/I x 100), rounded to the nearest tenth percent.
5. "Δ_{AVE} (%)" indicates the average of all "P" values for the parameter and subgroup noted.

1950518-100 – PCQ LIFE – Group II

SN		46-55 Lins	≥25 S_{sl}	≥50 S_{ft}	≥35 S_{sp}	≤2.5:1 VSWR
79	I	45.6	30	56	46	No Failures
	F	45.8	31	55	45	
	P	+0.4	+3.3	-1.8	-2.2	
31	I	45.8	–	55	–	
	F	45.8	30	53	45	
	P	0	0	-3.6	0	
54	I	45.8	28	–	–	
	F	46.0	27	55	46	
	P	+0.4	-3.6	0	0	
113	I	–	–	–	43	
	F	45.9	32	53	45	
	P	0	0	0	+4.7	
129	I	46.0	–	53	45	
	F	45.7	30	52	46	
	P	-0.7	0	-1.9	+2.2	
35	I	46.2	32	56	45	–
	F	N/A	N/A	N/A	N/A	Out
Δ_{AVE} (%)		0	-0.1	-1.5	+0.9	
MOISTURE – Group I and III						
23	I	45.2	25	55	46	No Failures
	F	45.4	30	53	45	
	P	+0.4	+20	-3.6	-2.2	
46	I	–	–	–	44	
	F	45.2	32	56	45	
	P	0	0	0	+2.3	
51	I	45.0	–	56	–	
	F	45.4	30	55	46	
	P	+0.9	0	-1.8	0	
85	I	45.5	33	56	43	
	F	46.2	32	57	40	
	P	+1.5	-3.0	+1.8	-7.0	
131	I	45.3	29	56	43	
	F	45.4	32	55	45	
	P	+0.2	+10.3	-1.8	+4.7	
134	I	46.0	32	57	44	
	F	45.8	30	55	46	
	P	-0.4	-6.3	-3.5	+4.5	
Δ_{AVE} (%)		+0.4	+3.5	-1.5	+0.4	

NOTES:
1. Dash indicates initial/final values are unchanged.
2. "I" indicates the parameter value at the in-process final electrical test (see Figure 5.1-3).
3. "F" indicates the parameter value after exposure to Group C, Subgroup II or Subgroup I/III testing, as noted.
4. "P" indicates the percentage changes from initial to final readings (F-I/I x 100), rounded to the nearest tenth percent.
5. "Δ_{AVE} (%)" indicates the average of all "P" values for the parameter and subgroup notes.

AD-A081 126 HUGHES AIRCRAFT CO FULLERTON CA GROUND SYSTEMS GROUP F/G 9/5
PHOTOLITHOGRAPHIC TECHNIQUES FOR SURFACE ACOUSTIC WAVE (SAW) DE--ETC(U)
DEC 78 A W DOZIER DAAB07-75-C-0044
UNCLASSIFIED HAC-FR-79-12-40-VOL-4 DELET-TR-75-0044-F-V-4 NL

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1950521-100 – PCLN LIFE – Group II

SN		27-33 Lins	≥20, 25 S_{sl}		≥50 S_{ft}	≥35 S_{sp}	≤35:1 VSWR
33	I	32.8	22	31	56	37	No Failures
	F	32.9	33	28	53	40	
	P	+0.3	+50.0	-9.7	-5.4	+8.1	
7	I	–	21	34	54	40	
	F	32.4	35	31	53	42	
	P	0	+66.7	-8.8	-1.9	+5.0	
97	I	–	22	33	58	42	
	F	31.9	35	31	56	41	
	P	0	+59.1	-6.1	-3.4	-2.4	
87	I	32.4	23	34	55	38	
	F	32.3	35	32	53	37	
	P	-0.3	+52.2	-5.9	-3.6	-2.6	
52	I	32.4	21	32	55	41	
	F	32.5	35	30	54	40	
	P	+0.3	+66.7	-6.3	-1.8	-2.4	
15	I	32.7	23	29	56	40	
	F	32.9	33	27	53	39	
	P	+0.6	+43.5	-6.9	-5.4	-2.5	
Δ_{AVE} (%)		+0.2	+56.4	-7.3	-3.6	+0.5	
MOISTURE – Group I and III							
89	I	–	22	33	56	38	No Failures
	F	31.3	34	30	54	36	
	P	0	+54.5	-9.1	-3.6	-5.3	
123	I	31.8	31	28	55	43	
	F	32.0	34	31	53	41	
	P	+0.6	+9.7	+16.7	-3.6	-4.7	
122	I	–	28	29	56	44	
	F	31.6	32	31	53	40	
	P	0	+14.3	+6.9	-5.4	-9.1	
141	I	32.6	27	27	54	43	
	F	32.8	35	33	53	40	
	P	+0.6	+29.6	+22.2	-1.9	-7.0	
84	I	32.4	22	35	–	–	
	F	32.6	35	33	56	40	
	P	+0.6	+59.1	-5.7	0	0	
155	I	32.4	27	29	52	43	
	F	32.7	35	31	50	41	
	P	+0.9	+29.6	+6.9	-3.8	-4.7	
Δ_{AVE} (%)		+0.5	+32.8	+5.3	-3.1	-5.1	

NOTES:
1. Dash indicates initial/final values are unchanged.
2. "I" indicates the parameter value at the in-process final electrical test (see Figure 5.1-3).
3. "F" indicates the parameter value after exposure to Group C, Subgroup II or Subgroup I/III testing, as noted.
4. "P" indicates the percentage changes from initial to final readings (F-I/I x 100), rounded to the nearest tenth percent.
5. "Δ_{AVE} (%)" indicates the average of all "P" values for the parameter and subgroup notes.

1950524-100 – TDL-100 LIFE – Group II

SN		98-102 f_o	24-30 Lins	≥17 S_{sl}	≥50 S_{ft}	≥35 S_{sp}	<4:1 VSWR
102	I	–	–	19	50	37	No Failures
	F	100.08	27	20	52	38	
	P	0	0	+5.3	+4	+2.7	
121	I	–	27	–	53	37	
	F	100.08	28	20	50	35	
	P	0	+3.7	0	-5.7	-5.4	
65	I	–	27	–	–	38	
	F	100.08	28	20	50	35	
	P	0	+3.7	0	0	-7.9	
43	I	–	–	–	–	39	
	F	100.08	27	20	50	35	
	P	0	0	0	0	-10.3	
41	I	–	27	–	50	39	
	F	100.08	28	20	51	35	
	P	0	+3.7	0	+2.0	-10.3	
88	I	–	–	–	50	39	
	F	100.10	27	20	53	38	
	P	0	0	0	+6.0	-2.6	
Δ_{AVE} (%)		0	+1.9	+0.9	+1.1	+5.6	
MOISTURE – Group I and III							
21	I	–	27	18	53	–	No Failures
	F	100.10	25	20	54	37	
	P	0	-7.4	+11.1	+1.9	0	
59	I	–	–	–	50	42	
	F	100.09	30	19	55	40	
	P	0	0	0	+10.0	-4.8	
115	I	–	–	–	50	35	
	F	100.09	26	20	53	36	
	P	0	0	0	+6.0	+2.9	
81	I	–	28	19	50	37	
	F	100.10	30	20	53	40	
	P	0	+7.1	+5.3	+6.0	+8.1	
27	I	–	–	20	50	41	
	F	100.08	29	19	52	36	
	P	0	0	-5.0	+4.0	-12.2	
53	I	–	–	–	50	41	
	F	100.08	29	20	52	36	
	P	0	0	0	+4.0	-12.2	
Δ_{AVE} (%)		0	-0.1	+1.9	+5.3	-3.0	

NOTES:
1. Dash indicates initial/final values are unchanged.
2. "I" indicates the parameter value at the in-process final electrical test (see Figure 5.1-3).
3. "F" indicates the parameter value after exposure to Group C, Subgroup II or Subgroup I/III testing, as noted.
4. "P" indicates the percentage changes from initial to final readings (F-I/I x 100), rounded to the nearest tenth percent.
5. "Δ_{AVE} (%)" indicates the average of all "P" values for the parameter and subgroup notes.

1950527-100 – TDL-200 LIFE – Group II

SN		198-202 fo	23-29 Lins	≥17 S_{sl}	≥50 S_{ft}	≥35 S_{sp}	≤3:1 VSWR
88	I	–	–	20	55	40	No Failures
	F	200.14	25	19	52	38	
	P	0	0	-5.0	-5.5	-5	
60	I	–	–	–	56	–	
	F	200.14	25	20	54	39	
	P	0	0	0	-3.6	0	
37	I	–	–	–	57	42	
	F	200.14	25	20	55	37	
	P	0	0	0	-3.5	-11.9	
47	I	–	27	19	54	43	
	F	200.16	26	18	56	38	
	P	0	-3.7	-5.3	+3.7	-11.6	
112	I	–	–	–	55	40	
	F	200.14	25	20	56	39	
	P	0	0	0	+1.8	-2.5	
107	I	–	–	20	–	39	
	F	200.13	26	19	54	38	
	P	0	0	-5.0	0	-2.6	
Δ_{AVE} (%)		0	-0.6	-2.6	-1.2	-5.6	
MOISTURE – Group I and III							
141	I	–	25	19	55	35	No Failures
	F	200.13	26	20	54	38	
	P	0	+4.0	+5.3	-1.8	+8.6	
136	I	–	26	–	–	36	
	F	200.11	25	19	54	39	
	P	0	-3.8	0	0	+8.3	
65	I	–	25	21	53	39	
	F	200.15	26	20	54	38	
	P	0	+4.0	-4.8	+1.9	-2.6	
23	I	–	27	19	51	38	
	F	200.14	25	20	55	39	
	P	0	-7.4	+5.3	+7.8	+2.6	
12	I	–	25	–	55	37	
	F	200.14	26	20	54	38	
	P	0	+4	0	-1.8	+2.7	
128	I	–	–	–	–	36	
	F	200.12	25	20	55	37	
	P	0	0	0	0	+2.8	
Δ_{AVE} (%)		0	+0.1	+1.0	+1.0	+3.7	

NOTES:

1. Dash indicates initial/final values are unchanged
2. "I" indicates the parameter value at the in-process final electrical test (see Figure 5.1-3).
3. "F" indicates the parameter value after exposure to Group C, Subgroup II or Subgroup I/III testing, as noted.
4. "P" indicates the percentage changes from initial to final readings (F-I/I x 100), rounded to the nearest tenth percentage.
5. "Δ AVE (%)" indicates the average of all "P" values for the parameter and subgroup notes.

APPENDIX XXVII
PILOT PRODUCTION YIELD DATA

HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

DEVICE DESCRIPTION BP-Q P/N 1950512-100

I. 18 Wafer starts, thru photolithography, @ 33 die/wafer = 594 die
- 2 11 % Poor photolithographic yield
- 2 11 % Scratched metallization from cap probe.
- 2 11 % Improper metallization thickness
- %

II. 12 Wafers @ 33 die per Wafer OR
396 Die to predice inspection
- 63 15.9 % Reject due to excess visual defects

III. 333 Post die inspection data
- 47 14.1 % Excess chipping
- 25 6.3 % Metallization scratched (cap probe)
- 17 4.3 % Handling damage
- 2 .5 % Metallization voids
- %
- 6 Unmounted spares

IV. 236 Die Mount & Bond
- %
- %

V. 236 Precap Electrical Test
- % f_o
- % β
- 1 .4 % L_{ins}
- % $S_{s.l.}$
- % $S_{f.t.}$
- % S_{spur}
- 4 1.7 % VSWR
- 1 .4 % Other Scratched metallization

VI. 230 Precap QC (Visual Inspection of Header)
- 11 4.8 % Foreign material (reworked)
- 1 .4 % Scratched metallization (bought off)
- %
- %

VII. 230 Seal, Mark, Leak Test
- 15 6.5 % Proj. weld leakers
- 7 3.0 % Solder leakers
- 1 .4 % Post seal lid deformation

(Proj. weld leakers, Solder leakers, Post seal lid deformation: Sn & Au plated pkgs.)
- 31 Unsealed

VIII. 176 Final Electrical Test and QC (External Visual only)
- 47 26.1 % VSWR
- 3 2.2 % L_{ins}
- 7 3.9 % β
- 2 Lost
- %

120 Delivered

DEVICE DESCRIPTION BP-LN P/N 1950515-100

I. 15 Wafer starts, thru photolithography, @ 32 die/wafer = 480 die
- 2 13.3% Poor photolithographic yield
- %
- %
- %

II. 13 Wafers @ 32 die per Wafer OR
416 Die to predice inspection
- 51 12.3% Reject due to excess visual defects

III. 365 Post die inspection data
- 15 4.2%
- %
- %
- %
- %
- 17 Unmounted spares

IV. 333 Die Mount & Bond
- %
- %

V. 333 Precap Electrical Test
- % f_0
- 4 1.2% β
- 22 6.6% L_{ins}
- 12 3.6% $S_{s.l.}$
- 9 2.7% Handling damage - die
- % S_{spur}
- 34 10.2% VSWR
- 1 .3% Other - Toroid damage during tune & test

VI. 251 Precap QC (Visual Inspection of Header)
- 1 .4% Metallization damage
- 1 .4% Metallization voids
- %
- %

VII. 249 Seal, Mark, Leak Test
- 13 5.2% Proj weld leak
- 12 4.8% Solder seal leaker
- %
- 2 Unsealed

$\}$ Sn & Au plated pkgs.

VIII. 202 Final Electrical Test and QC (External Visual only)
- 52 25% VSWR
- 4 2.0% β
- 2 1.0% L_{ins}
- %
- %

144 Delivered

HUGHES FULLERTON
Hughes Aircraft Company
Fullerton California

DEVICE DESCRIPTION PC-Q P/N 1950518-100

I. 24 Wafer starts, thru photolithography, @ 20 die/wafer - 480 die
- 2 8.3% Poor photolithographic yield
- %
- %
- %

II. 22 Wafers @ 20 die per Wafer OK
440 Die to predice inspection
- 97 22 % Reject due to excess visual defects

III. 343 Post die inspection data
- 9 2.6% Excessive chipping
- 10 2.9% Insoluble foreign material
- 5 1.5% Handling damage
- 6 1.7% Metallization voids due to lubricant attack through pinholes
- %
- 16 Unmounted spares

IV. 297 Die Mount & Bond
- 35 11.8% Die mounted incorrectly (drawing incorrect)
- 2 .7% Solder wicked over top of pin

V. 260 Precap Electrical Test
- % f_o
- 8 3.1 % Handling dame
- 12 6.5 % L_{ins}
- % $S_{s.t.}$
- 8 3.1 % $S_{r.t.}$
- 6 2.3 % S_{spur}
- 4 1.5 % VSWR
- 4 1.5 % Other - Transducer open

VI. 213 Precap QC (Visual Inspection of Header)
- %
- %
- %
- %

VII 213 Seal, Mark, Leak Test
- 51 24.0% Solder seal leak
- 1 .5% Proj Weld Leak Sn plate & gold plate pkgs
- 1 .5% Excessive solder
- 2 Unsealed

VIII. 159 Final Electrical Test and QC (External Visual only)
- 4 2.5% VSWR - 2 unsealed
- 1 .6% L_{ins}
- 2 1.3% $S_{s.t.}$
- *1 .6% S_{rt}
- %

152 Delivered

*Specimen also failed L_{ins}

DEVICE DESCRIPTION PC-LN P/N 1950521-100

I. 11 Wafer starts, thru photolithography, @ 45 die/wafer = 495 die

- ► 1 9.1 % Poor photolithographic yield
- ► ___ ___ %
- ► ___ ___ %
- ► ___ ___ %

II. 10 Wafers @ 45 die per Wafer OR

450 Die to predice inspection

- ► 117 26 % Reject due to excess visual defects

III. 333 Post die inspection data

- ► 48 14.4 % Excessive chipping
- ► 61 18.3 % Metal too thick
- ► 12 3.6 % Insoluble residue from dicing
- ► 5 1.5 % Metallization voids due to lubricant attack through resist pinholes.
- ► ___ ___ %
- ► ___ Unmounted spares

IV. 207 Die Mount & Bond

- ► 9 4.3 % Excessive RTV (improper mask, pattern too close to edge)
- ► ___ ___ %

V. 198 Precap Electrical Test

- ► 5 2.5 % L_{ins}
- ► 3 1.5 % S_{sp}
- ► 5 2.5 % VSWR
- ► 3 1.5 % Scratched die
- ► ___ ___ %
- ► ___ ___ %
- ► ___ ___ %
- ► ___ ___ %

VI. 182 Precap QC (Visual Inspection of Header)

- ► ___ ___ %
- ► ___ ___ %
- ► ___ ___ %
- ► ___ ___ %

VII. 182 Seal, Mark, Leak Test

- ► 6 3.3 % Cracked bead leak } All Sn plate pkgs
- ► 6 3.3 % Proj weld leak - Sn plate } All Sn plate pkgs
- ► 9 4.9 % Solder seal leak
- ► 0 Unsealed

VIII. 161 Final Electrical Test and QC (External Visual only)

- ► 1 .6 % Short
- ► 3 1.8 % L_{ins}
- ► 1 .6 % VSWR
- ► 1 .6 % S_{sp}
- ► 9 5.6 % Pins clipped

146 Delivered

DEVICE DESCRIPTION TDL-200 P/N 1950527-100

I. 31 Wafer starts, thru photolithography, @ 12 die/wafer = 372 die
- ► 4 12.9% Poor photolithographic yield
- ► 3 9.7% Handling damage
- ► %
- ► %

II. 24 Wafers @ 12 die per Wafer OR
288 Die to predice inspection
- ► 35 12.2% Reject due to excess visual defects

III. 253 Post die inspection data
- ► 13 5.1% Handling damage
- ► 17 6.7% Metallization voids - contaminated alcohol
- ► %
- ► %
- ► %
- ► Unmounted spares

IV. 223 Die Mount & Bond
- ► 3 1.3% Handling damage - die
- ► 4 1.8% Metallization damage during wire bonding

V. 216 Precap Electrical Test
- ► % f_o
- ► % β
- ► 3 1.4% L_{ins}
- ► % $S_{s.l.}$
- ► 4 1.9% $S_{f.t.}$
- ► % S_{spur}
- ► 8 3.7% VSWR
- ► % Other

VI. 201 Precap QC (Visual Inspection of Header)
- ► %
- ► %
- ► %
- ► %

VII. 201 Seal, Mark, Leak Test
- ► 41 20.4% Solder seal leak
- ► %
- ► %
- ► Unsealed

VIII. 160 Final Electrical Test and QC (External Visual only)
- ► 15 9.4 % VSWR
- ► 7 4.4 % L_{ins}
- ► %
- ► %
- ► 1 % Clipped pin

137 Delivered

DEVICE DESCRIPTION TDL-100 P/N 1950524-100

I. 43 Wafer starts, thru photolithography, @ 9 die/wafer = 387 die

- 2 4.7% Poor photolithographic yield
- 3 7.0% Overetched - Operator training
- ____ ____ %
- ____ ____ %

II. 38 Wafers @ ____ die per Wafer OR

342 Die to predice inspection

- 75 21.9% Reject due to excess visual defects

III. 267 Post die inspection data

- 35 13.1% Handling damage
- ____ ____ %
- ____ ____ %
- ____ ____ %
- ____ ____ %
- 0 Unmounted spares

IV. 232 Die Mount & Bond

- 5 2.2% Metallization damage during wire bonding
- ____ ____ %

V. 227 Precap Electrical Test

- ____ ____ % f_o
- ____ ____ % β
- 11 4.8% L_{ins}
- ____ ____ % $S_{s.l.}$
- ____ ____ % $S_{f.t.}$
- ____ ____ % S_{spur}
- 5 2.2% VSWR
- 1 .4% Other Damaged die

VI. 210 Precap QC (Visual Inspection of Header)

- 3 1.4% Scratched metallization
- ____ ____ %
- ____ ____ %
- ____ ____ %

VII. 207 Seal, Mark, Leak Test

- 40 19.3% Solder seal leak (all pkgs. hand soldered)
- ____ ____ %
- ____ ____ %
- ____ Unsealed

VIII. 167 Final Electrical Test and QC (External Visual only)

- 12 7.2% VSWR
- 2 1.2% L_{ins}
- ____ ____ %
- ____ ____ %
- ____ ____ %

150 Delivered

0 Overage

APPENDIX XXVIII
AUTOMATIC CAPACITANCE PROBE PROGRAM

```
000223          /52/'*';
000223          WRITE(LP)/4/'*',/20/'*',/36/'*',/52/'*';
000224          WRITE(LP)'****************************************************',
000225          /50/'***';
000225
000225
000225          ABORT: WRITE(TTP)'THIS ROW IS COMPLETE.';
000226          WRITE(TTF)'DO YOU WISH TO CONTINUE TESTING?(Y/N)';
000227          READ %ANX;IF ANX EQ Y THEN BEGIN K=0;L=0;GOTO START0;END;
000234          END;
00000   COMPILATION ERRS
```

```
000001          REM  *********   "*APQ1"   *******;
000001          SET PAGE 1024;DEVSS=6;
000003          DCL OUT(12)/'1','2','3','4','5','6','7','8','9','0','.','PFD'/;
000004          DCL MSSG[50],ANX,Y/'Y'/,N/'N'/,CAPV[DEVSS],CAPZERO[2];
000005          START0:
000005          FOR LINE=1 THRU 26 DO WRITE(TTP)'';
000007          WRITE(TTP)'PLACE THE PROBES OVER THE FIRST DEVICE , LEAVE THE';
000010          WRITE(TTP)'PROBES UP , AND PRESS THE START SWITCH';
000011          WRITE(TTP)''; WRITE(TTP)''; PAUSE 1;
000014          START1:
000014          IF L GE 2 THEN K=K+1;
000016          L=L+1;
000017          IF L EQ 1 THEN FOR LINE=1 THRU 26 DO WRITE(TTP)'';
000022          IF (L EQ 1) OR (L EQ 2) THEN CAPZERO[L]=0;
000024          IF L EQ 3 THEN BEGIN
000025          WRITE(TTP)'PROBE THE DEVICE AND PUSH THE START SWITCH';
000026          WRITE(TTP)'TO CONTINUE.';WRITE(TTP)'';WRITE(TTP)'';PAUSE 2;
000032          END;
000032          BN:
000032          IF (L EQ 1) OR (L EQ 3) THEN SET MA 000 010 ELSE SET MA 010 000;
000035          SET DA 101 101;
000036          AT 0;SUM=0;CAP=0;
000041          ENABLE MB;
000041    0000  SET F 000 000;
000042          ENABLE MA;
000042    0001  SET F 110 110;
000043          ENABLE TEST;
000044          SET R 110 110;
000045          CONN TCOM 3,6;
000046          SET PERIOD 10E-6,RNG0;
000047          CGEN TG1 1,4;
000050          SET TG1 DELAY 40E-9,RNG0;
000051          SET TG1 WIDTH 5E-6,RNG0;
000052          FORCE E0 0,RNG1;
000053          FORCE E1 5,RNG2;
000054          SET S0 0,RNG2;SET S1 0,RNG2;
000056
000056          SUBR TMS(TSTART,TSTOP,START,STOP,TG,RES);
000056          IF (TSTART LEQ TSTOP) OR (TSTOP LT 10E-9) THEN BEGIN
000057          RES=1;GOTO N7;END;T=TSTART;SET TG7 WIDTH 10E-9,RNG0;
000063          DELTA=TSTART-TSTOP;
000064          FAIL=0;
000065          N1:
000065          IF DELTA LT 0.10E-9 THEN BEGIN IF FAIL EQ 0 THEN RES=3
000070          ELSE RES=T;GOTO N7;END;DELTA=DELTA/2;SET TG7 DELAY T;
000074          SET START START;SET MAJOR 1,STOP;ENABLE TEST;
000077          READ(52,0)CRNK1;IF CRNK1 NEQ 0 THEN BEGIN IF T EQ TSTART
000102          THEN BEGIN RES=2;GOTO N7;END;FAIL=1;T=T+DELTA;GOTO N1;END;
000107          T=T-DELTA;GOTO N1;
000111          N7:MEASURE VARIABLE RES,LOG; END;
000112
```

```
WRITE(TTP)'';IF L EQ 1 THEN
WRITE(TTP)'THE TESTER IS NOW MEASURING THE J
                                          IG CAPACITANCE VALUES';
IF L EQ 3 THEN
WRITE(TTP)'THE TESTER IS NOW MEASURING THE D
                                        EVICE CAPACITANCE VALUES';

KC=1;
SKEW=40E-9;
REST=6060;
VMAX=(1E6*5)/(1E6+REST);
DCL SUM;
FOR V=1 THRU 49 DO BEGIN
SET S0 V/10,RNG2;
SET S1 V/10,RNG2;
EXEC TTIME (9,99E-6,20E-9,0,1,7,RES);
IF (RES GE 1) OR (RES LT 0) THEN GOTO SKPSUM;
SUM=SUM+(RES-SKEW);
SKPSUM:
END;
CAP=((SUM*.1)/(REST*VMAX)); FORCE E1 0,RNG2;
IF (L EQ 1) OR (L EQ 2) THEN BEGIN CAPZERO[L]=CAP;
WRITE(TTP)'';WRITE(TTP) 'CAPZERO=',CAPZERO[L];
GOTO START1;END;
IF (L EQ 3) OR (L EQ 4) THEN CAP=CAP-CAPZERO[L-2];


LAB1:CAPV[K]=CAP;WRITE(TTP)'';WRITE(TTP)'CAP=',CAP;WRITE(TTP)'';
WRITE(TTP)'';
IF L EQ 4 THEN BEGIN
IF K EQ DEVSS THEN GOTO ENDTEST;
WRITE(TTP)'MOVE TO THE NEXT DEVICE , LEAVE P
                                             ROBES UP , AND PRESS';
WRITE(TTP)'THE START SWITCH TO CONTINUE TESTING';L=0;
PAUSE K;END;GOTO START1;


ENDTEST:
FOR K=1 THRU DEVSS DO BEGIN J=(K-1)*5;NUM=CAPV(K);

IF NUM GT 1E-10 THEN NUM=99.9E-12;IF NUM LT 1E-12 THEN
NUM=1.0E-12;
FOR EXP=1 THRU 15 DO BEGIN
IF NUM LT 1 THEN NUM=NUM*10 ELSE GOTO JUMP1;END;

JUMP1:  FOR I=1 THRU 9 DO BEGIN ANS=NUM-I;
IF ANS LT 0.999 THEN BEGIN NUM=ANS;GOTO JUMP2;END;END;

JUMP2: J=J+1;IF (EXP GT 16) THEN GOTO JUMP3;
MSSG(J)=OUT(I);
IF EXP EQ 13 THEN BEGIN I=11;EXP=EXP+1;GOTO JUMP2;END;
NUM=NUM*10;EXP=EXP+1;
IF NUM LT 1 THEN BEGIN I=10;GOTO JUMP2;END;
GOTO JUMP1;
JUMP3:END;
```

```
000217          WRITE(LP)'**************************************************',
000220          /50/'***'
000220          WRITE(LP)/4/'*',/20/'*',/36/'*',/52/'*'
000221          WRITE(LP)
000222          /4/'*',/6/&MSSG(1),/7/&MSSG(2),/8/&MSSG(3),/9/&MSSG(4),
000222          /10/&MSSG(5),
000222          /14/&MSSG(6),/15/&MSSG(7),/16/&MSSG(8),/17/&MSSG(9),
000222          /18/&MSSG(10),
000222          /20/'*',/22/&MSSG(11),/23/&MSSG(12),/24/&MSSG(13),/25/&MSSG(14),
000222          /26/&MSSG(15),
000222          /30/&MSSG(16),/31/&MSSG(17),/32/&MSSG(18),/33/&MSSG(19),
000222          /34/&MSSG(20),
000222          /36/'*',/38/&MSSG(21),/39/&MSSG(22),/40/&MSSG(23),/41/&MSSG(24),
000222          /42/&MSSG(25),
000222          /46/&MSSG(26),/47/&MSSG(27),/48/&MSSG(28),/49/&MSSG(29),
000222          /50/&MSSG(30),
000222          /52/'*'
000222          WRITE(LP)
000223          /4/'*',/7/'PFD',/15/'PFD',/20/'*',/23/'PFD',
000223          /31/'PFD',/36/'*',/39/'PFD',/47/'PFD',
```

APPENDIX XXIX
CAPACITANCE PROBE DATA FOR BP-Q DEVICES

#6 BPQ 1950 Å
lot 51

STATIC TEST PLAN CAPS SN 1

1	6,66 PFD	5,71 PFD	1,49 PFD	1,47 PFD	1,48 PFD	1,28 PFD
2	8,30 PFD	6,75 PFD	6,83 PFD	6,69 PFD	8,31 PFD	6,23 PFD
3	8,21 PFD	6,56 PFD	8,14 PFD	6,69 PFD	8,28 PFD	8,27 PFD
4	8,20 PFD	99,89 PFD	8,28 PFD	6,53 PFD	8,15 PFD	8,83 PFD
5	8,15 PFD	6,579 PFD	8,17 PFD	6,46 PFD	7,92 PFD	99,89 PFD
6	7,97 PFD	6,539 PFD	8,12 PFD	6,48 PFD	7,12 PFD	6,179 PFD
7	8,22 PFD	6,549 PFD	8,13 PFD	6,42 PFD	8,02 PFD	6,209 PFD
8	8,09 PFD	6,529 PFD	8,12 PFD	6,42 PFD	7,89 PFD	6,049 PFD
9	7,86 PFD	6,499 PFD	8,14 PFD	6,32 PFD	7,67 PFD	5,919 PFD
10	99,89 PFD	4,179 PFD	99,89 PFD	6,32 PFD	7,57 PFD	5,889 PFD

HBQ 51-6

STATIC TEST PLAN CAPS SN 2

11	6,17 PFD	4,08 PFD	6,39 PFD	4,38 PFD	5,96 PFD	4,28 PFD

3

STATIC TEST PLAN CAPA SN 1

1	7,32 PFD	5,50 PFD	7,17 PFD	4,31 PFD	5,55 PFD	5,08 PFD
2	7,14 PFD	5,48 PFD	7,27 PFD	5,41 PFD	7,08 PFD	4,78 PFD
3	7,17 PFD	5,49 PFD	7,24 PFD	5,44 PFD	6,98 PFD	5,11 PFD
4	7,09 PFD	5,85 PFD	7,17 PFD	5,38 PFD	6,98 PFD	5,13 PFD
5	7,07 PFD	5,2[illegible] PFD	7,08 PFD	5,28 PFD	6,95 PFD	3,94 PFD
6	5,19 PFD	99,89 PFD	7,05 PFD	5,33 PFD	7,04 PFD	5,08 PFD
7	99,89 PFD	5,269 REU	7,02 PFD	5,25 PFD	5,18 PFD	4,11 PFD
	5,669 PFD	5,299 PFD	7,07 PFD	5,21 PFD	6,87 PFD	4,91 PFD
	6,989 PFD	4,839 PFD	99,89 PFD	5,08 PFD	6,78 PFD	4,88 PFD
	99,89 PFD	4,939 PFD	99,89 PFD	5,13 PFD	6,98 PFD	4,88 PFD
11	4,899 PFD	4,049 PFD	6,939 PFD	5,26 PFD	6,78 PFD	4,71 PFD

1349

1950

no book
15
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HUGHES-FULLERTON
Hughes Aircraft Company
Fullerton, California

1	6,879 PFD	5,199 PFD	2	6,929 PFD	99,89 PFD	3	5,29 PFD	4,81 PFD
4	6,669 PFD	5,189 PFD	5	6,959 PFD	5,149 PFD	6	6,58 PFD	4,79 PFD
7	6,759 PFD	5,139 PFD	8	6,699 PFD	5,019 PFD	9	4,51 PFD	4,74 PFD
10	6,639 PFD	5,119 PFD	11	6,799 PFD	5,009 PFD	12	6,64 PFD	99,89 PFD
13	4,529 PFD	5,929 PFD	14	6,729 PFD	4,979 PFD	15	6,83 PFD	99,89 PFD
16	6,539 PFD	5,039 PFD	17	6,669 PFD	4,299 PFD	18	6,81 PFD	4,789 PFD
19	6,519 PFD	4,939 PFD	20	6,629 PFD	5,019 PFD	21	4,87 PFD	3,839 PFD
22	6,089 PFD	4,679 PFD	23	6,629 PFD	5,019 PFD	24	6,63 PFD	4,679 PFD
25	6,329 PFD	4,919 PFD	26	5,679 PFD	5,089 PFD	27	6,60 PFD	4,589 PFD
28	6,339 PFD	4,799 PFD	29	99,69 PFD	3,899 PFD	30	6,22 PFD	4,489 PFD
31	6,129 PFD	4,729 PFD	32	6,399 PFD	4,789 PFD	33	6,83 PFD	4,379 PFD

Jo' 18 50"

4 wafer

Lot 51 #10
1850Å

HB9 51-10

2/15
15
29

STATIC TEST PLAN CAP SN 1 #4 lot 51 wafer #1

1.	1: 7.34 PFD	3.4[illegible] PFD	2: [illegible]	[illegible].49	3: 7.27 PFD	6.51 PFD
2	4: 7.22 PFD	5.55 PFD	5: 7.31	5.50	6: 7.83 PFD	5.83 PFD
3	7: 1.[illegible] PFD	1.[illegible] PFD	8: 7.22	5.45	9: 6.81 PFD	4.97 PFD
4	10: 7.93 PFD	5.47 PFD	11: 7.1[illegible]	1.[illegible]	12: 6.87 PFD	5.1[illegible] PFD
5	13: 6.16 PFD	5.[illegible]	14: 7.[illegible]	5.2[illegible]	15: 6.01 PFD	1.[illegible] PFD
6	16: 1.[illegible] PFD	4.4[illegible]	17: 1.[illegible]	[illegible]	18: 6.83 PFD	4.96 PFD
7.	19: 7.04 PFD	5.42	20: 5.1[illegible]	5.[illegible]	21: 1.[illegible] PFD	4.92 PFD
	22: 1.[illegible]	1.[illegible]	23: 1.[illegible]	1.[illegible]	24: 1.[illegible] PFD	~~6.84 PFD~~
9.	25: 5.27	5.1[illegible]	26: 7.[illegible]	5.1[illegible]	27: 6.77 PFD	4.[illegible] PFD
	28: 1.[illegible]	4.[illegible]	29: 1.[illegible]	5.21	30: 6.50 PFD	4.53 PFD
11	1.[illegible] PFD	1.[illegible]	5.[illegible]	5.[illegible]	6.36 PFD	1.[illegible] PFD

6,939 PFD	4,349 PFD	6,389 PFD	5,369 PFD	6,92 PFD	4,889 PFD
6,929 PFD	5,299 PFD	7,119 PFD	5,869 PFD	6,87 PFD	5,889 PFD
6,919 PFD	5,279 PFD	7,889 PFD	5,289 PFD	6,83 PFD	5,849 PFD
6,879 PFD	4,349 PFD	6,959 PFD	5,289 PFD	6,97 PFD	5,829 PFD
6,869 PFD	5,289 PFD	6,949 PFD	5,269 PFD	6,81 PFD	99,89 PFD
6,749 PFD	5,139 PFD	6,949 PFD	5,879 PFD	6,18 PFD	4,969 PFD
6,769 PFD	5,159 PFD	6,819 PFD	5,139 PFD	6,78 PFD	4,929 PFD
3,559 PFD	5,119 PFD	6,829 PFD	5,129 PFD	6,59 PFD	4,789 PFD
6,889 PFD	5,869 PFD	6,759 PFD	3,899 PFD	6,77 PFD	4,719 PFD
6,529 PFD	4,849 PFD	99,89 PFD	5,889 PFD	6,82 PFD	4,569 PFD
6,389 PFD	4,889 PFD	5,389 PFD	4,879 PFD	6,29 PFD	99,89 PFD

1.	7,109 PFD	1,009 PFD	1,000 PFD	1,009 PFD	1,00 PFD	1,000 PFD
2	6,939 PFD	5,209 PFD	7,049 PFD	8,289 PFD	6,51 PFD	99,09 PFD
3	6,409 PFD	4,749 PFD	6,049 PFD	3,989 PFD	6,78 PFD	4,709 PFD
4	6,819 PFD	5,139 PFD	6,989 PFD	5,299 PFD	4,63 PFD	2,209 PFD
5	5,409 PFD	1,000 PFD	1,009 PFD	1,009 PFD	1,00 PFD	1,009 PFD
6	1,009 PFD	1,000 PFD	1,009 PFD	1,009 PFD	1,00 PFD	1,009 PFD
7	5,019 PFD	4,719 PFD	6,589 PFD	4,909 PFD	5,01 PFD	4,449 PFD
	6,879 PFD	5,239 PFD	7,849 PFD	3,679 PFD	6,68 PFD	4,789 PFD
9	6,739 PFD	5,219 PFD	7,019 PFD	5,219 PFD	6,83 PFD	4,819 PFD
	6,759 PFD	5,189 PFD	7,029 PFD	5,209 PFD	6,73 PFD	4,859 PFD

1800 ft

15
24

1.	6,939 PFD		5,289 PFD	5,939 PFD	2	5,889 PFD	6,85 PFD	3	4,989 PFD
2.	6,829 PFD	4	5,249 PFD	6,879 PFD	5	5,129 PFD	6,73 PFD	6	99,89 PFD
3.	6,889 PFD	7	4,969 PFD	6,969 PFD	8	5,869 PFD	6,77 PFD	9	4,799 PFD
4.	4,699 PFD	10	5,169 PFD	6,909 PFD	11	5,159 PFD	6,75 PFD	12	4,809 PFD
5.	5,189 PFD	13	5,239 PFD	6,889 PFD	14	5,159 PFD	6,59 PFD	15	4,789 PFD
6.	6,749 PFD	16	5,199 PFD	6,849 PFD	17	3,789 PFD	6,63 PFD	18	4,689 PFD
7.	6,789 PFD	19	4,969 PFD	99,89 PFD	20	5,839 PFD	6,52 PFD	21	4,839 PFD
8.	6,689 PFD	22	4,889 PFD	6,729 PFD	23	4,929 PFD	6,33 PFD	24	4,819 PFD
9.	7,319 PFD	25	5,529 PFD	7,889 PFD	26	5,489 PFD	6,96 PFD	27	5,879 PFD
10	7,189 PFD	28	5,459 PFC	7,239 PFD	29	5,339 PFD	7,85 PFD	30	5,829 PFD
11	7,899 PFD	31	5,419 PFD	7,239 PFD	32	5,379 PFD	6,93 PFD	33	5,879 PFD

Checked

4	10 6,989 PFD	5,359 PFD	11 7,889 PFD	5,389 PFD	12 99,89 PFD	5,859 PFD
5	13 6,949 PFD	4,869 PFD	14 5,929 PFD	5,299 PFD	15 6,919 PFD	99,89 PFD
6	16 6,989 PFD	5,219 PFD	17 7,889 PFD	5,289 PFD	18 6,899 PFD	3,789 PFD
7	19 6,339 PFD	4,159 PFD	20 6,959 PFD	5,199 PFD	21 6,929 PFD	4,979 PFD
8	22 6,829 PFD	4,969 PFD	23 6,329 PFD	5,239 PFD	24 6,819 PFD	4,919 PFD
9	25 6,759 PFD	5,169 PFD	26 6,959 PFD	99,89 PFD	27 6,849 PFD	4,869 PFD
10	28 6,859 PFD	3,939 PFD	29 99,89 PFD	4,789 PFD	30 6,669 PFD	4,789 PFD
11	31 6,759 PFD	4,969 PFD	32 6,769 PFD	5,849 PFD	33 6,419 PFD	4,589 PFD

Wafer #9

#10

Lot 52

1900Å

1.	6,749 PFD	5,289 PFC	6,889 PFD	5,179 PFD	6,79 PFD	4,899 PFD		
				2		3		
2	5,929 PFD	4,129 PFD	6,889 PFD	5,879 PFD	6,71 PFD	1,889 PFD		
	4		5		6			
3	1,889 PFD	1,889 PFD	1,889 PFD	3,819 PFD	6,83 PFD	5,889 PFD		
	7		8		9			
4	6,569 PFD	4,989 PFD	6,739 PFD	2,739 PFD	6,64 PFD	4,729 PFD		
	10		11		12			
5	6,639 PFD	5,899 PFD	6,599 PFD	99,89 PFD	6,69 PFD	4,689 PFD		
	13		14		15			
6	6,159 PFD	5,869 PFD	6,639 PFD	4,939 PFD	6,58 PFD	4,629 PFD		
	16		17		18			
7	6,519 PFD	4,979 PFD	99,89 PFD	5,889 PFD	6,34 PFD	4,489 PFD		
	19		20		21			
8	6,519 PFD	4,869 PFD	4,979 PFD	4,899 PFD	6,18 PFD	4,449 PFD		
	22		23		24			
9	7,179 PFD	5,389 PFD	7,179 PFD	5,229 PFD	6,88 PFD	4,189 PFD		
	25		26		27			
10	6,969 PFD	5,339 PFD	7,879 PFD	5,289 PFD	6,92 PFD	4,959 PFD		
	28		29		30			
11.	6,879 PFD	4,289 PFD	7,189 PFD	5,319 PFD	6,83 PFD	4,939 PFD		
	31		32		33			

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APPENDIX XXX
CAPACITANCE PROBE DATA FOR BP-LN DEVICES

7.57 PFD	7.57 PFD	7.57 PFD	8.029 PFD	7.37 PFD	8.19 PFD	7.47 PFD	3.219 PFD
8.14 PFD	7.65 PFD	8.04 PFD	8.119 PFD	7.48 PFD	8.25 PFD	7.18 PFD	1.989 PFD
8.37 PFD	7.67 PFD	7.85 PFD	3.429 PFD	7.31 PFD	3.36 PFD	7.57 [illegible]	7.879 PFD
8.42 PFD	7.89 PFD	8.59 PFD	3.399 PFD	8.17 PFD	8.19 PFD	7.68 PFD	8.319 PFD
8.83 PFD	6.40 PFD	8.76 PFD	3.639 PFD	7.84 PFD	8.70 PFD	7.69 PFD	8.459 PFD
8.88 25 PFD	7.84 PFD	8.18 26 PFD	8.499 PFD	9.89 27 PFD	8.79 PFD	7.63 28 PFD	2.899 PFD
8.81 29 PFD	7.68 PFD	8.69 30 PFD	8.399 PFD	8.489 31 PFD	8.59 PFD	7.52 32 PFD	2.489 PFD

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7.38 PFD	7.11 PFD	7.14 PFD	7.749 PFD	7.64 PFD	8.01 PFD	7.28 PFD	3.149 PFD
7.71 PFD	7.21 PFD	7.92 PFD	7.849 PFD	7.27 PFD	8.13 PFD	7.00 PFD	7.819 PFD
8.02 PFD	7.57 PFD	8.07 PFD	7.889 PFD	7.74 PFD	8.30 PFD	5.91 PFD	7.849 PFD
8.00 PFD	7.60 PFD	8.21 PFD	3.789 PFD	7.90 PFD	8.27 PFD	7.44 PFD	7.839 PFD
7.97 PFD	7.49 PFD	8.31 PFD	3.149 PFD	8.00 PFD	8.06 PFD	7.58 PFD	8.169 PFD
7.65 PFD	7.42 PFD	8.44 PFD	7.939 PFD	7.77 PFD	8.41 PFD	7.55 PFD	3.539 PFD
8.26 PFD	7.48 PFD	7.76 PFD	3.589 PFD	8.13 PFD	8.47 PFD	7.69 PFD	8.349 PFD
8.45 PFD	7.55 PFD	8.63 PFD	3.399 PFD	8.24 PFD	8.43 PFD	7.55 PFD	8.219 PFD

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Hughes Aircraft Company
Fullerton, California

1	1: 8.18 PFD · 7.81 PFD	2: 8.18 PFD · 3.089 PFD	3: 7.929 PFD · 8.45 PFD — 5 opens	4 ok: 7.58 PFD · 3.269 PFD
2	5: 8.48 PFD · 8.85 PFD	6: 8.38 PFD · 7.949 PFD	7: 7.879 PFD · 8.68 PFD	8: 7.86 PFD · 8.719 PFD
3	9: 8.88 PFD · 8.13 PFD	10: 8.48 PFD · 8.499 PFD	11: 8.359 PFD · 4.12 PFD — 4 open all	12: 8.86 PFD · 8.859 PFD
4	13: 8.37 PFD · 8.23 PFD	14: 8.83 PFD · 8.289 PFD — 3/10 open	15: 8.669 PFD · 8.86 PFD	16: 8.15 PFD · 8.839 PFD
5	17: 8.96 PFD · 8.24 PFD	18: 8.38 PFD · 8.749 PFD — 2/10	19: 8.789 PFD · 8.88 PFD	20: 8.25 PFD · 8.979 PFD
6	21: 9.18 PFD · 99.89 PFD	22: 9.01 PFD · 8.849 PFD	23: 8.459 PFD · 9.12 PFD	24: 8.91 PFD · 5.819 PFD
7	25: 9.04 PFD · 8.299 PFD	26: 8.54 PFD · 8.819 PFD	27: 8.829 PFD · 9.18 PFD	28: 7.94 PFD · 3.589 PFD — 5/10
8	29: 9.25 PFD · 8.289 PFD	30 ok: 9.17 PFD · 3.679 PFD	31: 8.789 PFD · 8.98 PFD	32: 8.19 PFD · 4.859 PFD — open

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	No.			No.			No.			No.		
1	1	7.97 PFD	7.73 PFD	2	8.11 PFD	2.749 PFD OK	3	7.82 PFD	3.74 PFD OK	4	6.98 PFD	3.229 PFD 7U 2cc
2	5	8.39 PFD	7.70 PFD	6	8.18 PFD	8.279 PFD	7	8.89 PFD	8.43 PFD	8	7.61 PFD	8.359 PFD
3	9	8.42 PFD	7.97 PFD	10	8.68 PFD	99.89 PFD	11	8.13 PFD	4.28 PFD	12	7.96 PFD	8.259 PFD
4	13	8.40 PFD	8.04 PFD	14	8.08 PFD	8.469 PFD	15	8.41 PFD	8.82 PFD	16	8.14 PFD	3.779 PFD op
5	17	8.70 PFD	8.12 PFD	18	8.17 PFD	4.549 PFD 2½	19	8.59 PFD	3.18 PFD 70 2cc	20	8.29 PFD	8.729 PFD
6	21	8.69 PFD	8.21 PFD	22	8.45 PFD	8.429 PFD	23	8.55 PFD	8.77 PFD	24	7.94 PFD	6.719 PFD
7	25	8.84 PFD	8.23 PFD	26	8.59 PFD	8.469 PFD	27	8.41 PFD	8.66 PFD	[illegible]	7.78 PFD	8.559 PFD
8	29	8.74 PFD	8.17 PFD	30	8.65 PFD	8.589 PFD	[illegible]	7.89 PFD	8.59 PFD	[illegible]	7.50 PFD	8.359 PFD

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8.22 PFD	7.61 PFD	7.92 PFD	2.979 PFD	7.84 PFD	8.19 PFD	7.44 PFD	8.299 PFD
8.23 PFD	7.58 PFD	8.15 PFD	8.159 PFD	7.85 PFD	3.19 PFD	7.35 PFD	3.199 PFD
8.34 PFD	7.83 PFD	8.34 PFD	7.949 PFD	8.18 PFD	1.88 PFD	7.65 PFD	8.439 PFD
8.36 PFD	7.93 PFD	8.61 PFD	8.129 PFD	8.32 PFD	8.67 PFD	7.85 PFD	8.579 PFD
8.66 PFD	8.04 PFD	8.50 PFD	8.479 PFD	8.47 PFD	8.52 PFD	6.95 PFD	8.629 PFD
8.71 PFD	8.00 PFD	8.76 PFD	8.539 PFD	7.1[illegible] PFD	3.74 PFD	7.94 PFD	8.649 PFD
8.80 PFD	7.91 PFD	7.86 PFD	8.529 PFD	8.42 PFD	8.88 PFD	7.92 PFD	8.749 PFD
8.86 PFD	8.07 PFD	8.48 PFD	8.809 PFD	7.92 PFD	8.59 PFD	7.87 PFD	3.349 PFD

7.00 PFD	7.30 PFD	8.16 PFD	2.589 PFD	7.73 PFD	3.03 PFD	7.45 PFD	3.219 PFD
8.19 PFD	7.59 PFD	8.26 PFD	8.239 PFD	7.88 PFD	8.40 PFD	7.34 PFD	3.289 PFD
8.44 PFD	7.74 PFD	7.96 PFD	3.239 PFD	7.86 PFD	7.24 PFD	7.58 PFD	3.249 PFD
9.33 PFD	7.91 PFD	8.28 PFD	8.079 PFD	8.24 PFD	5.96 PFD	7.74 PFD	3.469 PFD
8.62 PFD	7.97 PFD	8.72 PFD	8.029 PFD	8.40 PFD	3.77 PFD	7.55 PFD	3.409 PFD
8.63 PFD	8.03 PFD	8.87 PFD	8.189 PFD	8.46 PFD	8.59 PFD	7.96 PFD	3.589 PFD
8.81 PFD	8.10 PFD	8.97 PFD	8.559 PFD	8.83 PFD	8.81 PFD	8.01 PFD	3.909 PFD
8.91 PFD	7.76 PFD	8.61 PFD	3.629 PFD	8.58 PFD	8.76 PFD	7.61 PFD	3.359 PFD

1.	1: 7,89 PFD / 1,35 PFD	2: 8,80 PFD / 8,239 PFD	3: 7,91 PFD / 8,74 PFD	4: 7,55 PFD / 5,469 PFD
2.	5: 8,30 PFD / 7,68 PFD	6: 8,30 PFD / 8,269 PFD	7: 7,75 PFD / 8,52 PFD	8: 7,81 PFD / 3,729 PFD
3.	9: 8,40 PFD / 2,94 PFD	10: 8,21 PFD / 3,249 PFD	11: 7,56 PFD / 8,71 PFD	12: 7,61 PFD / 8,349 PFD
4.	13: 8,37 PFD / 8,00 PFD	14: 8,62 PFD / 8,079 PFD	15: 8,37 PFD / 3,55 PFD	16: 7,80 PFD / 8,579 PFD
5.	17: 8,82 PFD / 8,09 PFD	18: 8,72 PFD / 8,159 PFD	19: 8,52 PFD / 8,49 PFD	20: 8,07 PFD / 1,089 PFD
6.	21: 8,89 PFD / 8,04 PFD	22: 8,91 PFD / 8,689 PFD	23: 8,30 PFD / 3,79 PFD	24: 8,18 PFD / 8,749 PFD
7.	25: 9,00 PFD / 8,16 PFD	26: 8,30 PFD / 8,699 PFD	27: 8,61 PFD / 3,74 PFD	28: 8,06 PFD / 3,829 PFD
8.	29: 8,92 PFD / 7,97 PFD	30: 8,97 PFD / 3,889 PFD	31: 8,64 PFD / 3,53 PFD	32: 8,02 PFD / 8,669 PFD

1	7.76 PFD	7.22 PFD	7.41 PFD	1.449 PFD	7.68 PFD	8.29 PFD	7.31 PFD	3.169 PFD
2	8.06 PFD	7.44 PFD	8.09 PFD	8.029 PFD	7.37 PFD	8.24 PFD	7.87 PFD	8.019 PFD
3	8.27 PFD	7.68 PFD	8.30 PFD	2.939 PFD	7.81 PFD	3.13 PFD	7.35 PFD	8.109 PFD
4	8.26 PFD	7.04 PFD	8.50 PFD	8.149 PFD	8.00 PFD	8.48 PFD	7.48 PFD	7.939 PFD
5	8.50 PFD	7.68 PFD	8.49 PFD	8.049 PFD	8.22 PFD	8.35 PFD	7.57 PFD	8.309 PFD
6	8.55 PFD	6.98 PFD	8.55 PFD	3.609 PFD	8.16 PFD	8.82 PFD	7.45 PFD	8.429 PFD
7	8.64 PFD	4.43 PFD	7.93 PFD	3.519 PFD	8.36 PFD	8.71 PFD	7.54 PFD	7.729 PFD
8	8.61 PFD	7.69 PFD	8.69 PFD	1.009 PFD	8.38 PFD	3.43 PFD	7.60 PFD	8.309 PFD

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7.59 PFD	7.15 PFD	6.89 PFD	2.889 PFD	7.21 PFD	8.12 PFD	6.84 PFD	3.889 PFD
7.76 PFD	7.13 PFD	7.91 PFD	1.889 PFD	7.19 PFD	7.85 PFD	6.49 PFD	3.159 PFD
7.93 PFD	7.32 PFD	8.81 PFD	2.959 PFD	7.64 PFD	4.41 PFD	6.98 PFD	7.889 PFD
7.89 PFD	7.58 PFD	8.27 PFD	1.889 PFD	7.74 PFD	8.13 PFD	6.92 PFD	1.889 PFD
8.49 PFD	7.48 PFD	8.34 PFD	4.579 PFD	7.86 PFD	3.39 PFD	7.93 PFD	7.989 PFD
8.48 PFD	7.61 PFD	7.46 PFD	3.629 PFD	7.34 PFD	8.36 PFD	7.58 PFD	8.169 PFD
8.61 PFD	7.51 PFD	7.29 PFD	1.889 PFD	7.94 PFD	8.41 PFD	7.71 PFD	8.169 PFD
8.64 PFD	7.28 PFD	8.67 PFD	3.449 PFD	8.89 PFD	3.66 PFD	7.52 PFD	3.369 PFD

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1	7.98 PFD	7.75 PFD	7.89 PFD	8.26 PFD	7.51 PFD	8.46 PFD	8.42 PFD	8.14 PFD
2	8.11 PFD	7.78 PFD	8.07 PFD	8.31 PFD	7.87 PFD	8.58 PFD	6.86 PFD	8.34 PFD
3	8.22 PFD	7.88 PFD	8.33 PFD	8.34 PFD	7.95 PFD	8.71 PFD	7.48 PFD	8.43 PFD
4	2.75 PFD	8.81 PFD	2.37 PFD	8.32 PFD	2.27 PFD	8.61 PFD	1.86 PFD	8.51 PFD
5	2.75 PFD	8.16 PFD	2.51 PFD	99.89 PFD	2.36 PFD	3.94 PFD	7.52 PFD	8.37 PFD
6	8.51 PFD	8.14 PFD	8.30 PFD	8.629 PFD	8.31 PFD	8.61 PFD	7.86 PFD	99.89 PFD
7	8.57 PFD	8.13 PFD	8.48 PFD	8.739 PFD	8.83 PFD	8.88 PFD	7.61 PFD	8.799 PFD
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